STUDIES ON SHRIMP HARVESTING TECHNIQUES IN AQUACULTURE

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of the requirements
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(Mariculture)

by

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July 2003

Dedicated to
My Parents

CERTIFICATE

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सारांश

लाभदायक पारंपरिक झींगा व्यवसाय में झींगा प्रग्रहण तकनीक़ मुख्य भूमिका अदा करती है। यह एक श्रमिक भरा व्यवसाय है। लेकिन भारत में झींगा संवर्धन क्षेत्र में प्रग्रहण तरीकों की जानकारी की कमी महसूस किया जाता है। संवर्धित झींगों के प्रग्रहण में मुश्किलों को सामना करना पडता है, विशेषकर खेतों में, जहाँ पूरा नहीं निकला जा सकता है। खेतों से झींगों के प्रग्रहण में भिन्न प्रकार के तकनीकों, जैसे, स्लूइस जाल परिचालन, कास्ट जाल, क्लोम जाल को प्रयुक्त किया जाता है और विविध स्तरों पर हाथ से भी चुग लेता है।

अध्ययन के लिए वाइपिन द्वीप में (एरणाकुलम जिला, केरल) स्थित 6 मौसमी और 6 बारहमासी फार्मों को चुन लिया था। पारंपरिक झींगा फार्मों में - मौसमी और बारहमासी में से झींगों के प्रग्रहण के लिए विविध प्रग्रहण तकनीकों को अपनाया गया और उनकी संरचना, निर्माण बारीकी और चालन के तरीकों के बारे में विस्तृत अध्ययन किया गया । मौसमी और बारहमासी दोनों फार्मों में संचालित मुख्य गिअर प्रणाली है स्लूइस नेट। अन्य गिअर जैसे क्लोम जाल, कास्ट नेट और हाथ-चुगन से कभी कभी और अंतिम प्रग्रहण के दौरान प्रग्रहण किया जाता है। भिन्न गिअरों का चलाने की तीव्रता और इन मत्स्यन तकनीकों द्वारा उत्पन्न झींगों का अध्ययन, मौसमी और बारहमासी फार्मों के लिए अलग अलग से किया गया । विभिन्न प्रग्रहण प्रणाली से अवतरित झींगों के प्रजाति संगठन, लम्बाई सांख्यकी, लिंग अनुपात और विविध जाति के झींगों के कुल वज़न आदि का चर्चा की गई है। क्लोम जाल और कास्ट जाल के पकड क्षमता और क्लोम जाल के वरणीयता पर भी अध्ययन किया गया। पारंपरिक झींगा खेतों से प्रग्रहित झींगों के क्षमता पर प्रभाव डालने वाले घटक जैसे ज्वार-बाटा, चान्द्र पक्ष, जल का प्रवाह दर और स्लूईस गेट के प्रकाश तीव्रता का भी विस्तृत रूप से अनुसंधान किया गया। मौसमी और बारहमासी खेतों के आर्थिक पक्षों का, विशेषकर प्रग्रहण मुद्दों पर ध्यान देते हुए विश्लेषण किया गया ।

Abstract

Shrimp harvesting techniques play a major role in the efficient and profitable operation of traditional shrimp farms. It is a labour intensive operation. However, there is a paucity of information of harvesting techniques in the traditional sector of shrimp culture in India. Problems are encountered in harvesting cultured shrimps especially in the farms, which are not fully drainable. Various harvesting techniques such as sluice net operation, cast netting, gill netting, complete draining of the farms and hand picking are deployed at different stages to harvest the shrimp from the farms.

Six seasonal and six perennial farms located at Vypeen Island (Ernakulam District, Kerala) were selected for the study. Different harvesting techniques deployed for harvesting shrimps in the traditional shrimp farms, both seasonal and perennial, were studied in detail with respect to design, construction details and methods of operation. Sluice nets are the principal gear system operated in both the seasonal and perennial farms. Harvesting using other gears such as gill net, cast net and hand picking are done periodically and also during the final harvest. The Intensity of operation of different gears and details on the production of shrimp from these fishing techniques have been worked out separately for seasonal and perennial farms. The species composition, length statistics, sex ratio and total weight of different species of shrimps landed in the different harvesting systems have been discussed. The catching efficiency of gill nets and cast nets, and selectivity of gill nets have also been studied. Major factors influencing the efficiency of shrimp harvest from traditional shrimp farms, such as lunar phases, tide, flow rate of water and intensity of light at sluice gates, have been investigated in detail. Economic aspects of seasonal and perennial farms with special emphasis on the harvesting issues have been analysed.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER - I

INTRODUCTION

1. INTRODUCTION

India occupies 5^{th} position in the production of cultured shrimp after Thailand, Ecuador, Indonesia and China (Yap, 2001). Shrimp has been the prima donna of the Indian fishery exports since early 1970s and still continues to be so. The export of fishery product from India has crossed the Rs. 5,000 crore mark during 1999-2000 and shrimp export contributed 71.24 % of our total export earnings, (Anon, 2002). India offers enormous scope for developing coastal aquaculture of fin fishes and shell fishes. Out of the identified area of 1.2 million ha suitable for land based coastal aquaculture, only about 15 % is utilized. The shrimp production from inshore capture fishery is remaining stagnant. The only way out for India to augment its shrimp production to meet the ever increasing consumer demand and to maintain its position as one of the leading shrimp producing and exporting countries of the world, would be through aquaculture.

India is one of the countries blessed with rich natural resources for fish and shrimp farming along the coast line of 8500 km. Against an estimated brackishwater area of 11,90,000 ha all along the coast line of India suitable for shrimp culture, only 1,41,873 ha are under shrimp farming till 1998-99 (Anon, 2001b). Aquaculture of shrimps in coastal brackishwater bodies has been recognized as one of the highly potential areas for increasing shrimp production. It also derives economic benefits such as better use of unproductive and marginally productive lands, augmentation of export and foreign exchange earnings, and establishment of ancillary industries. As the farms are located in rural areas, generation of employment opportunities and upliftment of the socio-economic conditions of the rural people are added advantages. Only traditional extensive method of culture is practised in 70 % of this area even now.

Subsistence level aquaculture was being practised in the coastal states of Kerala, Karnataka, Goa and West Bengal for many generations. India ventured into a highly profitable aquaculture practice only in the late eighties. Shrimp culture, traces its origin to southeast Asia, where for centuries, farmers raised incidental crops of wild shrimp in tidal fish ponds. The earliest record of aquaculture of Penaeidae is found in Chinese history in 8^{th} century BC. Japanese literature refers to penaeid culture in 730 AD. For hundreds of years, shrimp culture had only been considered as a secondary crop in traditional fish farming systems in many Asian countries. Modern shrimp culture has actually started in 1930s.

Knowledge on the life cycle of shrimps has been an important step in understanding the requirements to obtain desired results in hatchery and grow out procedures. Commercial shrimp grow out attempts has been made in Ecuador in 1960s and in US in late 1960s. The Ecuadorian industry has been based on *Litopenaeus vannamei* and *L. stylirostris* and has been started by accident when a broken banana farm allowed shrimp to enter. Consequent on the repair of the dyke, a crop of shrimp has been produced Stickney (1994). Presently, shrimp culture has grown into one of the largest and most important aquaculture crops worldwide.

Based on FAO time series data, in 1984 there have been only 33 countries resorting to farmed shrimp production (Yap, 2001). This has increased to 51 in 1989 and has remained so up to 1991. But by 1996 the number of shrimp producing countries has risen to 60. Once shrimp hatcheries has begun supplying large quantities of seeds to farmers, the production of farm raised shrimp increased rapidly. The explosion of the industry has continued to early 1990s until problems have begun worldwide with disease outbreaks and decline in water quality. In recent years, production has been on the increase again, as ways of controlling diseases have been found and water recirculation and reuse technologies are being more widely practised.

The acceleration in shrimp culture activity in the early 1990s has been influenced by a combination of factors. Economic conditions together with innovative culture technologies have promoted the demand for cultured shrimp. The most important technological breakthroughs for countries producing farm raised shrimp have been the commercialization of shrimp hatchery technology and improvements in overall pond management practices.

Cultured shrimps are generally superior in quality to their trawled counterparts because the former reaches to the processor sooner than the latter which are sometimes damaged as they experience enormous strain in the codend. The shrimp farmer can usually schedule production and minimize delays between harvesting and processing of crops.

Though many studies have been made on various aspects of shrimp culture, an extensive study on the harvesting aspects in the traditional sector is lacking. Problems in harvesting cultured shrimp are often encountered in the ponds which are not fully drainable and that complete retrieval of the stock is not effected with existing type of gear and harvesting techniques.

Partial harvest and total harvest techniques are employed for harvesting shrimps. In India, different methods of harvesting such as sluice gate filtration (sluice net), cast netting, gill netting, complete draining and hand picking are employed at different stages. Kerala state has an age-old tradition in shrimp farming practised in low lying areas of *pokkali* fields in the coastal region, located adjacent to backwaters and estuaries. These areas are fully tide-fed with salinity variations according to the monsoon. Natural stocking of mixed varieties of shrimp seeds takes place from adjoining creeks during tidal influx. The juveniles depend on natural food and in some farms supplementary feed is given. Water intake and draining is carried out through sluice gates depending on local tides. Harvesting is done periodically around full moon and new moon periods. The success of shrimp farming to a great extent depends upon the efficiency of harvesting. Shrimp quality is largely related to harvest techniques and post harvest handling. By efficient harvesting techniques, the entire stock can be collected without damage at minimum cost.

The main objectives of the study are:

- Documentation with technical design specifications of existing shrimp harvesting techniques in traditional aquaculture systems;
- To study the intensity of operation and productivity of gear systems in traditional shrimp culture systems;
- To study the comparative efficiency and selectivity of selected harvesting techniques in traditional shrimp culture systems;
- To find out the effect of lunar periodicity on the efficiency of shrimp harvesting in aquaculture;
- To study the influence of light and rate of flow of water in harvesting shrimps in shrimp filtration systems; and
- To study the economics of traditional shrimp farming and harvesting techniques.

CHAPTER - 2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In India, the rice field shrimp culture is an age old practice. Paddy field shrimp filtration process (*Chemeenkettu)* of Central Kerala, (Menon, 1954; Gopinath, 1956 ; Raman and Menon, 1963; George *et al.*, 1968 ; George, 1974; Purushan, 1995; 1996a,b&c; Unnithan, 1985; 2000); the shrimp and fish culture practised in '*Bheries*' of West Bengal, where it is known as '*Bhasa-badha*' fishery (Pillay, 1954; Saha *et al.,* 1986) and shrimp filtration of '*Khar*' lands (*Gazani* farms*)* of Karnataka (Nagaraj and Neelakantan, 1982) and '*Khazan*' lands of Goa (Unnithan, 2000) are some of the traditional farming practised today. Traditional practice of shrimp farming has also been reported in Orissa (Mohapatra, 1988; Mohanty, 1988) and certain other maritime states of the country (Alagarswami, 1990).

State-wise details of shrimp farming areas in India are given in Table 2.1. In Kerala, the water spread of brackishwater lakes and the adjacent low lying fields and mangrove swamps is estimated to be about 2,42,000 ha (Tharakan, 1991). The largest of this resource is the Vembanad lake with a length of 96.5 km from Kodungallur in the north to Alappuzha in the south covering a total water area of 25,600 ha. It receives freshwater from the Periyar river in the north and Pampa river in the south, in addition to the large number of irrigation channels, drains and rivulets. In Kerala, only 13,646 ha have been utilized so far for shrimp culture against 65,231 ha of brackishwater available for culture (Verghese, 2001).

"Shrimp filtration", a traditional system of shrimp farming in paddy fields, is practised in more than 12,511 ha of the low lying coastal brackishwater fields in Kerala State (Table. 2.2.) These fields, spread over mainly in the coastal villages of Alleppey, Ernakulam and Trissur districts, and confluent with the Vembanad lake through canals, are subjected to tidal

Table 2.1. State-wise details of shrimp farming areas in India

State	Estimated potential area (ha)	Area covered (ha)	Ranking
Andhra Pradesh	1,50,000	71,000	1
West Bengal	4,05,000	42,067	2
Kerala	65,000	14,705	3
Orissa	31,600	8,000	4
Karnataka	8,000	3,564	5
Tamil Nadu	56,000	1,087	6
Goa	18,500	650	7
Maharashtra	80,000	426	8
Gujarat	3,76,000	316	9
Pondicherry	800	22	10

Source: *Aqua International*, 2002

Table 2.2. District-wise details of traditional shrimp filtration fields in Kerala.

Name of district	Area of traditional shrimp filtration fields (ha)	Area of culture farms both in public and private sectors (ha)	Total
Kasaragod	-	8.91	8.91
Kannur	501.51	20.56	522.07
Kozhikode	-	-	-
Malappuram	-	-	-
Thrissur	898.21	58.66	956.87
Ernakulam	10,597.01	131.46	10,728.47
Kottayam	15.38	48.61	63.99
Alapuzha	475.35	9.24	484.59
Kollam	24.00	74.56	98.56
Thiruvananthapuram	-	2.22	2.22
Total	12,511.46	354.22	12,865.68

Source: *ADAK, 1991*

influence. The farming system involves entrapment of juvenile shrimp brought in by the tidal water in the fields and retaining them by filtration at regular intervals. These fields are used for growing paddy during the south-west monsoon season (June-September) and for farming shrimps during the rest of the year. During the south-west monsoon, the heavy precipitation makes the waters of Vembanad lake almost freshwater, and the paddy fields are inundated by freshwater. During this period, a special variety of paddy called "*Pokkali*", which is tolerant to salinities up to 8 ppt, is grown in these fields. As the salinity of the water in the feeder canals increases during October to April the paddy cannot be grown in the fields and the fields are leased out to shrimp farmers.

Stocking is done by placing a light at the sluice gate during night and letting in the tidal water into the fields during high tide. Along with the tidal water juvenile shrimps/fishes from the adjoining backwater areas enter the field due to attraction by the light. When the tidal water starts receding during low tide, a closely tied screen made of bamboo or arecanut tree strips is inserted across the sluice gate and only the water is let out trapping all the juvenile shrimps/fishes that have entered the field. This mode of entrapment is continued at every high tide throughout the period of operation. Harvesting of shrimps, begins from mid December by operating a conical net fixed at the sluice gate during low tide and is known as filtration. It is done at dawn or dusk for 5-9 days around every new moon and full moon period during which maximum tidal amplitude is experienced (locally known as *Thakkom*). The final harvesting will be done at the end of the season by operating sluice net, cast net, gill net and by hand picking. This is locally known as *kalakkipiditham* or *kettukalakkal* (George *et al.,* 1968; Unnithan, 1985; 2000; Kurup *et al.,* 1993).

The relatively deeper brackishwater impoundments which are not suitable for growing paddy are called perennial fields (locally known as *varshakketu*). The size of these fields range from 2-75 ha (George and Suseelan, 1980) and these fields are used for growing shrimps throughout the year. The method of stocking and harvesting are similar to those adopted in the case of seasonal fields. Since such areas are deeper, the bottom portion of the water column will be saline making it suitable for the growth and survival of shrimp during monsoon periods also. In India, this type of shrimp culture is practised in the brackishwater bheries of West Bengal and paddy fields adjoining Vembanad lake in Kerala (Muthu, 1978b).

The estuarine phase of penaeid shrimps is taken advantage of for brackishwater farming (Mohammed and Rao, 1971), besides large scale exploitation of juveniles from brackishwater environment by various traditional fishing methods in many Southeast Asian countries. In India, the extensive brackishwater systems available on the west and the east coast serve as a good nursery grounds for many coastal species of penaeid shrimps contributing to the fishery. (George, 1962; Panikkar and Menon, 1956; Subramanyam, 1965; Mohammed and Rao, 1971; Selvakumar *et al.*, 1977; Suseelan and Kathirvel, 1982; Achuthankutty and Nair, 1983; Achuthankutty, 1988).

Cardover (1987) has given an outline of farm design and harvesting. Fernandez *et. al.* (1996) has worked on reduction of quantity of moulting shrimps before harvesting. Naik and Pascoe (1996) have worked out bioeconomic model for optimal harvesting. Ramakrishna *et al.* (1982) have reported various methods of harvesting in mixed culture. Different pond harvesting techniques have been described by Fast (1991). The effects of harvesting methods on population structure, growth and yield in fresh water ponds have been studied by Siddiqui *et al.* (1995).

The major problem encountered when harvesting shrimp is their burrowing habit in the pond bottom. This makes it difficult to harvest them in a single netting operation. In the context of intensive culture in large areas, the harvesting technology to catch all the shrimps in the field is necessary (Silas, 1980). Delmendo and Rabanal (1995) pointed out that effective harvesting is one of the problems in *P. monodon* cultivation in Philippines. Shigueno (1969) is of the opinion that the most effective method of harvesting shrimps from ponds is by draining the pond water. Selective harvesting of cultured shrimp helps to obviate the need for complete draining of pond water (Sakthivel, 1998). Harvesting strategies like partial harvest/drain harvest and selective partial harvest are used in Japan for *P. japonicus* culture (Hirasawa 1985). Traps and pound nets have been reported by Shigueno (1978) and Chien and Liao (1988). Pump equipped drag nets (Shigueno, 1969) and electric drag nets (Shigueno 1978; Chien and Liao, 1988; Fast *et al.*, 1989 and Hussenot, *et al.,* 1991) are used in Japan and Taiwan for harvesting shrimps from aquaculture ponds. Seines are also used for partial harvest of ponds after lowering the water level so that the water and shrimp are confined to the canals (Menasveta and Higuchi 1983; SEAFDEC, 1984; Faulkner, 1998). Fish pumps are used in the US during complete drain harvest (Reisnger, 1985). Naik and Pascoe (1996) have studied the optimal harvesting strategies for sea bream and tiger shrimp culture.

At present, reports on the existing shrimp harvesting techniques in mariculture in India are scanty. Shrimp harvesting methods are mentioned briefly by Ghosh *et al.* 1985. Mohanty (1998), Pani (1995), Prabhudeva *et al.* (1990), Purushan (1996 a, b & c), Rajyalakshmi (1980) and Unnithan (1985). Detailed works on the design aspects, the intensity of the gear operations, the efficiency and selectivity of the gear systems used in aquaculture have not been studied so far. The present study examines in depth the technical profiles of different harvesting techniques for shrimp in the traditional culture systems, which include selective harvesting, efficiency of the prevailing gears used for harvesting and the influence of lunar periodicity, tide, light and flow of water on the shrimp catch. These studies can help in improving technical and economic efficiency of the shrimp harvesting systems in aquaculture.

Harvesting techniques for shrimp varies depending upon the type of aquaculture farms. Primitive and age old methods like fishing without gear (hand-picking), plunge basket, traps and other traditional methods (Gudger, 1952; George *et al.*, 1968; Anon, 1984; Unnithan, 1985) to modern methods like electric nets (Tseng, 1988; Fast, 1991; Agrawal, 1999) and the pump systems (James and James, 1993) are employed for harvesting shrimp in aquaculture. Methods of harvesting cultured shrimp have been described by a few (Kathirvel, 1978; Fast, 1991; Anon, 1999a; Stickney, 1994). Selective partial harvest is achieved by using nets with appropriate mesh size (Hirasawa, 1985). Various types of indigenous prawn fishing gears of Kerala were reported by many (Hornell, 1938; Bal and Banerjee, 1951; Anon, 1951; Kurien and Sebastian, 1986).

Studies to assess the yield from shrimp filtration farms and the rate of growth of the different shrimp species has been carried out by many workers (Panikkar, 1937; Menon, 1954; Gopinath, 1956; Panikkar and Menon, 1956; Raman and Menon, 1963; George *et al.*, 1968; George, 1974; Gopalan *et al.*, 1982; Verghese *et al.*, 1982; Jose *et al.*, 1987; Mathew and George, 1987; Kurup *et al.*, 1992; Mathew, 1993; Pillai and Krishnan, 1998; Chandramohan *et al.*, 1999; Purushan, 1989,1995, 1996a,b,c, 1989; Unnithan, 1985, 2000; and Srinath *et al.*, 2000). However, intensity of gear usage and the productivity from these different gears have not been worked out.

A few studies have been carried out on the catch efficiency and selectivity of gill nets and trammel nets (Acosta and Apppledoorn, 1995 and Thomas *et al.*,1993). Comparative catch efficiency of different materials in gill nets was done by Lawler (1950), Molin (1950,1956) Giesel (1953), Anon (1954), Shabtay (1956), Pycha (1962), Steinberg (1964), Shimozaki (1964), Mathai and George (1972), Shon (1978), Klust (1982), Radhalakshmi and Nayar (1985), Njoku (1991), and Thomas *et al.* (2003). The commercial application of polyamide in gill nets was reported by Firth (1950). Studies have been carried out on the comparative merits of synthetic nets over nets made of natural fibres in terms of catch. Carrothers (1962), Honda and Osada (1964), Zaucha (1964), Anon (1959a,b) and Klust (1959 and 1960). PE gill nets were experimented along with nylon (Steinberg, 1964). PP material was recommended by Carter and West (1964) for gill nets and Pajot

(1980a&b), and (Pajot and Das, 1981; 1984) attempted polyethylene for substituting polyamide in large mesh gill nets.

Work on selectivity of gill nets has been carried out by many workers Baranov (1914), Hodgson (1927 and 1933), Baranov (1948), Havinga and Deedler (1949), Olsen (1959) Mc Combie and Fry (1960), Mc Combie (1961), Nomura (1961), Holt (1963), Joseph and Sebastain (1964), Regier and Robertson (1966), Sulochanan *et al.* (1968, 1975), Mc Combie and Berst (1969), Hamley and Regier (1973), Hamley (1975), Yatsu and Watanabe (1987), Karunasinghe and Wijayarantne (1991), Reis and Pawson (1992), Acosta and Appledoorn (1995), Sreekrishna *et al.* (1972), Panicker *et al.* (1978); Shon (1985), Mathai *et al.* (1993), Salvanes (1991), A proper mesh size aids in obtaining the maximum yield. (Kennedy, 1950; Peterson, 1954; Mc Combie, 1961). Studies on the selectivity of gill net for shrimps are scanty and are mostly related to comparative efficiency with respect to material difference and design aspects (Mathai *et al.*, 1990; George, 1991: Thomas *et al.*, 1993). Thomas *et al.* (2003) carried out studies on the length frequency distribution of *P. indicus*. Not much work has not been done on the efficiency of cast nets. A comparative study of several types of small scale fishing gear was conducted by George *et al.* (1974) in the Cochin region.

Comparative studies on different materials for gill nets were also carried out by several workers in India (George and Mathai, 1972; Khan *et al.*, 1975; Radhalakshmi and Nayar, 1985; Pillai *et al.*, 1989; Mohan Rajan *et al.*, 1991; George, 1991; and Thomas, 2001).

Influence of moon and tide in the catch is reported by Hickling (1946), Rounsefell and Everhart (1953), Liu (1957). Observations on the lunar and tidal influence on catch has also been reported by Indian authors (Jayaraman *et al.*, 1959; Subramanyam, 1965; Bhat *et al.*, 1967; Mathai *et al.*, 1971; Kagwade, 1972 and Pati,1981). The effects of tidal and lunar phases on the penaeid prawn seed abundance were studied by Ganga *et al.* (1990) and Vasudevan and Subramoniam (1985). The shrimp catch fluctuate with lunar periodicity (Courtney *et al.*, 1996; Racek, 1959; Ruello, 1975 and Griffiths, 1999). The influence of lunar phase on catch and size composition of prawns in stake nets has been studied by Menon and Raman (1961), Raman and Menon (1963), Subramanyam (1965), Copeland (1965), George *et al.* (1998) and Thomas *et al.* (1999), Iverson and Idyll (1959) and Ingle *et al.*, (1959) stated that the prawn catch is very poor during full moon. Racek (1959) distinguished distinct lunar and diurnal abundance in prawn catches. Griffiths, (1999) studied the effects of lunar periodicity on catches of *P. lebejus* in an Australian coastal lagoon to determine the abundance of prawn during lunar period. Investigations in this direction have been initiated both by Indian and foreign workers in recent years (Liu, 1957; Subramanyam, 1965; Nomura, 1959, 1961; Mathai *et al.*,1971; Otubusin, 1990; Beyst *et al.*, 2002).

Light is also one of the factors influencing catch. Brandt (1972) reported that fishing with light existed since ancient times. Fish behaviour and reaction to light in general have been studied by several workers (Maeda, 1951; Wickham,1973; Kawamoto,1955 and Tamura,1959). Kurien *et al.* (1952) carried out studies on the catch of *Penaeus indicus* in Chinese dip nets using different lights. The influence of light of different strength and colour and the efficiency of various types of bulbs on fish attraction has been carried out by Borisov (1951), Imamura (1958, 1959); Imamura and Koike (1959), Kawamoto (1955,1959), Kusaka (1965); Yoshimuta and Mitsugi (1963). The reaction of crustaceans to direct and diffused light were reported by Schallck (1943). The catch of penaeid prawns have also been shown to vary in response to factors such as light intensity (Wassenberg and Hill, 1994), tidal cycles and salinity (Vance *et al.*, 1994).

Studies on the economics of aquaculture systems in India have been carried out by Singh and Pandey (1968) and Jayarajan *et al.* (1987). Rani *et al.* (1993), and Reddi (1980) have dealt with economics of scientific shrimp culture in an intensive scale in Andhra Pradesh. Economics of various brackishwater shrimp farming systems have been reported by Greenfield

(1975), George, (1978), Gopalan *et al.* (1978), Mammen *et al.* (1979), Hirasawa and Walford (1979) Srivastava *et al.* (1983), Griffin *et al.* (1985), Ayappa, (1985), Hirasawa (1985), Israel *et al.* 1985), Fast *et al.* (1990) and Cha *et al.* (1997). Marketing aspects of shrimps were studied by Rajendran (1980), Devarajan (1983), Rao *et al.* (1985), Jayaraman (1987), Houston and Nieto (1988) and Chidambaran and Sounder Rajan (1990). Pai *et al.* (1982), Jose *et al.* (1987), George (1974, 1978); Gopalan *et al.* (1978), Gopalan *et al.* (1982), Gopalan and Purushan, (1981), Raje and Radade (1980), Purushan (1987), Sathiadhas *et al.* (1989) and Mathew (1993) carried out studies on the yield and economics of the traditional shrimp culture practices.

CHAPTER - 3

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The Cochin backwaters form a part of the Vembanad lake, the largest backwater system in Kerala, which extends between latitudes 9° 28' E and 10° 10' N and longitudes 76° 13' and 76° 30' E. The two outlets of the lake into the Arabian sea are at Cochin and at Munambam, through which seawater influx is established during tides. The main source of freshwater for the lake is the rivers Periyar and Muvattupuzha with their tributaries Ithipuzha, Meenachil, Manimala, Pamba and Achankoil.

3.1. Study area

Vypeen is a coastal island located along the latitude 9° 58' – 10° 11' N, longitude 76° 10' – 76° 15' E in the central part of Kerala State, south India. It lies parallel to the main land and is separated from it on the eastern side by northern extension of the Vembanad lake. The Cochin and Azhikode bar mouths form the southern and northern boundaries of the island, while on the western side is the Arabian sea. The island is about 25 km long, wider near the middle and narrow at the southern and northern regions. The island has extensive marshy low lands, paddy fields and a net work of tidal canals. About 1170 ha of fields distributed all over the island are presently utilized for shrimp culture and most of these farms are situated adjacent to the canal system and connected with sluice gates, and some of these farms open directly to the backwater. Farms from Vypeen island were selected for the work owing to the large water bodies and good number of seasonal and perennial shrimp farms where traditional, extensive and scientific shrimp culture are being practised.

The present investigation was carried out in the shrimp culture systems situated on the low lying areas in Vypeen island, adjacent to the Cochin backwaters. These culture systems are connected to the backwater either directly or though canals, and receive saline water from the backwater during high tides.

A pilot survey was conducted, to fix the sampling sites in the low-lying areas around Cochin, where shrimp culture is being practised in a traditional way. Based on this survey, 6 seasonal shrimp culture farms and 6 perennial shrimp culture farms (Fig. 3.1.) were randomly selected at Vypeen island, Cochin for the studies. Field surveys were conducted in all these sites to collect the required data on design, construction and operation of harvesting systems. The mode of operation of the gear was monitored at the respective sites during the period of harvest. The details of the seasonal and perennial farms selected in Vypeen island, for the work is given in Table 3.1. a & b. Shrimp farms of size ranging from 2 ha to the largest shrimp farm 77.6 ha were selected for making a comparative study on the various aspects of shrimp harvesting undertaken on these farms.

The materials for this study were collected at fortnightly intervals during night from November 1999 to April 2001 from the selected seasonal and perennial shrimp aquaculture farms. Filtration is carried out during 9 days in each phase of the moon, *i.e.*, four days preceding and four days succeeding the full moon or new moon day as the case may be and this period is locally known as *thakkam*. During this period, the ebb tide will be such that it is possible to operate the sluice bag net during dusk or dawn hours when the movement and other activities of shrimps are seen to be much favourable (Purushan, 1996a).

3.2. Shrimp harvesting techniques with design specifications

The technical specifications of the different harvesting systems, its design, construction and mode of operation were collected from different aquaculture farms following a prescheduled proforma (Miyamoto, 1962). Additional data on the shrimp harvesting gear and its operation were collected from publications of the different research organizations administrative departments and non-governmental organizations. The

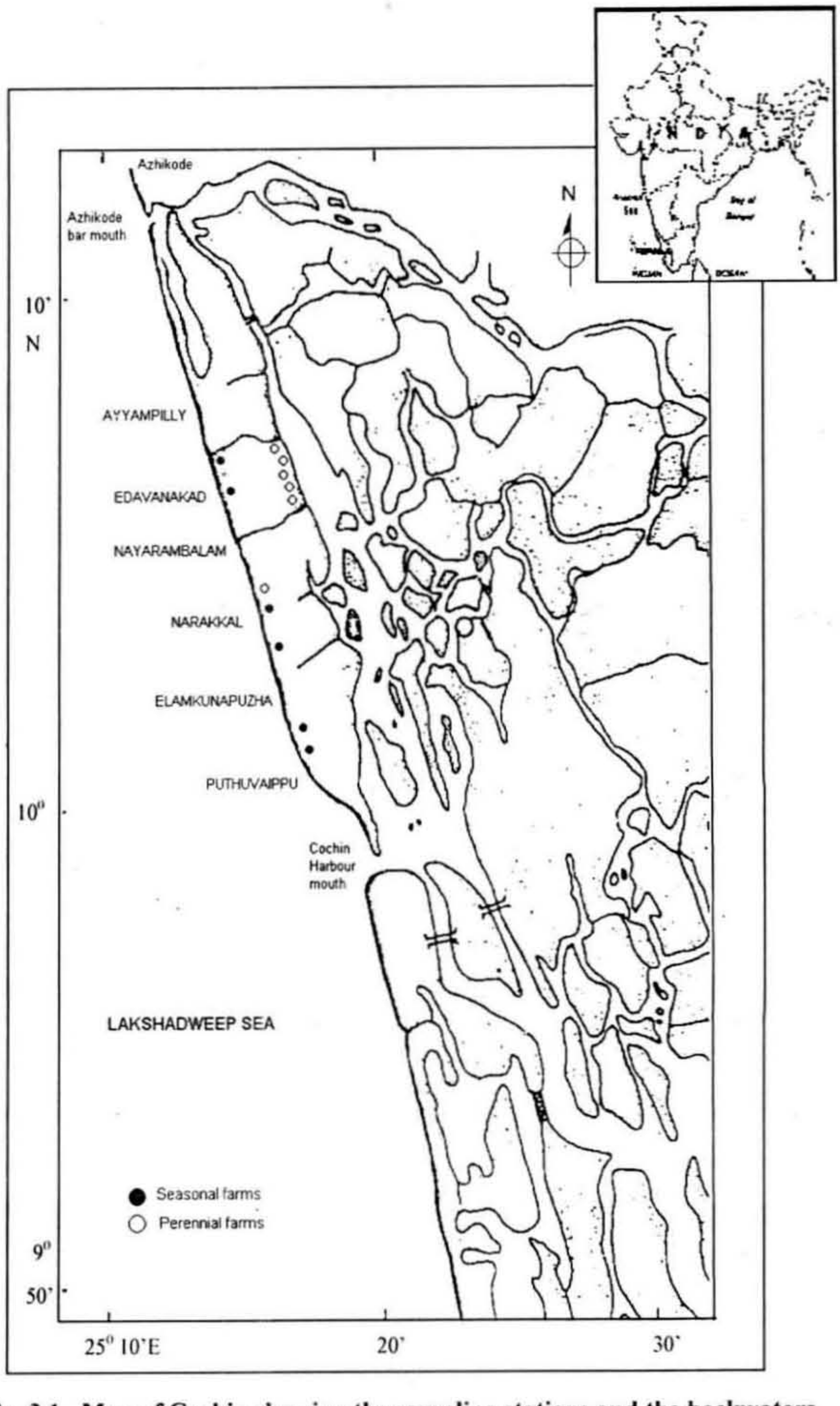


Fig. 3.1. Map of Cochin showing the sampling stations and the backwaters

Table 3.1. Shrimp culture farms selected in Vypeen island, Cochin, Kerala

(a) Perennial ponds

Sl. No.	Name of Farm	Size (ha)	Location
1	*Kannupillai*	77.6	Edavanakad
2	*Kochikaran*	19.2	Kuzhipulli
3	*Narakkal*	16.8	Narakkal
4	*Pasuekar*	10.6	Nayarambalam
5	*Sashi*	4.0	Puthuvypeen
6	*Jayan*	2.0	Puthuvypeen

(b) Seasonal ponds

Sl. No.	Name of Farm	Size (ha)	Location
1	*Kuttikatadi*	13.2	Kuzhipulli
2	*Fishery*	12.0	Kuzhipulli
3	*Appuende*	11.5	Nayarambalam
4	*Veliya*	7.2	Kuzhipulli
5	*Cheriya*	4.4	Kuzhipulli
6	*Forty*	3.2	Kuzhipulli

different gear designs drawn to scale were documented following the norms of FAO Catalogue of Fishing Gear Designs (Nedelec, 1975).

3.3. Productivity of gear systems

The shrimp production from each farm by different gears was estimated based on 10 % random sample in the case of cast net and gill net and for handpicking and sluice net total landings of the gear were collected separately for each farm. Details were also collected from the register maintained separately for this purpose by the lessee of the respective farms. In the case of gill net, the total catch is presented as catch (kg) obtained in 1,000 m^{-2} of netting per hour (kg.1,000 m^{-2}. h^{-1} and in kg.ha^{-1}), cast net (kg.h^{-1} and kg.ha^{-1}), bag net (kg. h^{-1} and kg. ha^{-1}) and in the case of hand picking it is given in catch in kg. h^{-1}person^{-1}. Month-wise and season-wise total and average yield of the farm and contribution of the different harvesting gear were also calculated. Simultaneous operation of bag net and gill nets was carried out in two perennial farms during *thakkam* at the time of harvest on an experimental basis to assess the difference in catch and length classes of different species of shrimps landed in the respective gear.

3.4. Data on morphometrics

The data on the biological aspects collected was used to study the gear efficiency, selectivity of the gear and to study the effect of lunar periodicity on the shrimp catch. A representative sample of the catch landed from the different harvesting systems *viz.*, sluice net, cast net, gill net, drag net and hand picking was taken from the respective farms. The species composition, species-wise sex ratio and length frequency of individual shrimp caught were recorded from each harvesting gear operated in the farms. Total length from rostrum tip to tail tip were measured to the nearest mm for each species (Sparre *et al.*, 1989). In the case of filtration net, the setting time and hauling time of the sluice net was taken and catch per unit effort calculated. Analysis of variance of the catch and size composition were worked out with respect to different lunar phases. The selectivity was estimated by indirect method proposed by Holt (1963).

3.5. Influence of light and rate of flow of water in shrimp harvesting

A perennial shrimp filtration farm having two numbers of sluice gates on the same side were selected for this study. The intensity of light during these experiments was recorded using a lux meter. The flow of water during the experiments was observed using a water current meter designed by CIFT and readings on salinity and temperature were taken using a Salinity Temperature Meter developed by CIFT (Sivadas, 1978, 1980). Species-wise catch data was recorded and data analysed statistically.

3.6. Data on the economics of different harvesting techniques

Data on the economics of operation of the 6 seasonal and 6 perennial traditional farms from Vypeen island was collected to study the economics of different harvesting systems in shrimp aquaculture.

The main tools used for the collection of the data were the pre-tested questionnaire. The data collected included economic information such as capital investment and other fixed overheads, seed cost, feed cost, harvesting cost, details of catch from different types of harvesting techniques and price. The economic efficiency was analysed using return on investment.

Materials and methods are given in detail in the forthcoming respective chapters.

CHAPTER - 4

SHRIMP HARVESTING TECHNIQUES

4. SHRIMP HARVESTING TECHNIQUES

4.1. Introduction

Methods for harvesting shrimp are diverse and varied depending upon the requirements of each area. Primitive and age old methods like fishing without gear (hand-picking), plunge basket traps and other traditional methods (Gudger, 1952; George *et al.*, 1968) to modern methods like electric nets (Tseng, 1988; Fast, 1991; Agrawal, 1999) and the pump systems (James and James, 1993), are employed for harvesting shrimp in aquaculture. The traditional gear like traps, drag nets, bag nets, cast nets, gill nets and advanced fishing techniques like pump equipped drag net and electric shocker are still in vogue in aquacultural practices for harvesting cultured shrimps around the world. Methods of harvesting cultured shrimp have been described by a few (Kathirvel, 1978; Fast, 1991; Anon, 1999a; Stickney, 1994). Cultured shrimp quality is largely related to harvest techniques and post harvest handling. The shrimps must be harvested within a short time period once it has been reared to a sufficient size for marketing. Some factors like the characteristic behavior of the shrimps are to be considered prior to and during harvesting. A major advantage of shrimp culture over shrimp capture from the wild is the greater potential control that the culturist has over many of the factors affecting size, quality and value of the shrimp (Fast, 1991).

Species specific behaviour is an important consideration when selecting a harvest method. Some species such as *P. vannamei and P. merguiensis* are relatively easy to harvest by draining the pond as they normally run with the drain water whereas some species like *P. monodon* and *P. indicus* do not always run readily with the drain water and may either strand or burrow into the bottom. Harvesting of ponds is easier when they are constructed in regular shape with properly sloped banks, proper depth, easy access by vehicles, large drain lines that allow rapid and complete emptying and the incorporation of a harvest basin near the drain. Many ponds lack one or more of these features. The use of canals within the ponds create faster water currents at the termination of the drain harvest, as well as much reduced bottom areas where the shrimps are likely to remain (Fast, 1991).

The type of harvest is also influenced depending on whether the crop consists of a single cohort or multiple cohorts. Some aquaculturists, employ a technique known as 'thinning' or periodic selective harvesting of the crop. As and when the shrimp reach market size, they are removed from the system. The selective partial harvest is achieved by using nets with appropriate mesh size which allows the smaller shrimp to escape. Juveniles are added as replacement after each such harvesting. These strategies are used in Japan for the culture of *P. japonicus* (Hirasawa, 1985).

Harvesting methods can be broadly divided into partial harvesting and total harvesting. Different fishing gear and methods are employed depending on the type of harvesting. Partial harvesting may be done after reducing the water level to the maximum possible extent and harvesting the shrimps by using traps, pound nets, gill nets or cast nets and complete or total harvest is usually done with the bag net placed near the sluice gate or by gradual draining of the pond to concentrate the shrimps in the pond canals and catching them using drag net, scoop net or by hand picking (Anon, 1984; Unnithan, 1985). The design, technical characteristics and method of operation of different gear are essential for further improvement of the methods.

Various types of indigenous fishing gears of Kerala were reported by many (Hornell, 1938; Bal and Banerjee, 1951; Anon, 1951; Kurien and Sebastian, 1986; Kurup and Samuel, 1985). However, reports on classification and the design details of fishing gears used in aquaculture systems are scanty. An attempt was made through this study to broadly group the fishing techniques and document the design details of the different harvesting gears used in traditional shrimp aquaculture systems.

4.2. Materials and Methods

A survey with reference to shrimp harvesting systems in aquaculture was conducted in southern states of India; Kannur, Panangad, and Vypeen in Kerala, Mangalore in Karnataka, Visakhapatnam in Andhra Pradesh, and Mandapam, Ramanad in Tamil Nadu. These states were selected as they have maximum areas utilized for shrimp culture. Both traditional as well as farms set up on modern practices were selected for the study.

The gear survey was conducted following Miyamoto (1962) and the technical specifications and design details of the gear and mode of operation were recorded. Based on proforma of Miyamoto (1962), the dimension details such as general dimensions, material, mesh size, twine size, hanging coefficient, construction details, floats, singers were collected, for different types of gear. The design details were prepared according to FAO (1975) and for description of the gear the general rules proposed by Percier (1959) were followed. In case of bag nets and cast nets, the width of the netting panels or sections was drawn according to half of the stretched netting and the depth according to the fully stretched netting. In case of gill nets, the length was drawn according to the length of the float line and depth according to the fully stretched netting. Other outline drawings of the gear, it's rigging and details of accessories were not drawn to scale but essential dimensions were given.

Denier system was used for representing linear deinsity of the netting material (1000 m of a single yarn weighing 1 g = 1 denier). In the case of monofilament material, diameter of the material is given as this is the common designation followed. Metric system is adopted throughout for dimensions. The size of the cast net is designated by the radius or the circumference of the net.

The shape of the netting in the case of gill net and cast net is indicated by the cutting rate at its edges. Horizontal and vertical lines in the gear drawing indicate 'T' cut or 'N' cut. Bar cuts are marked as 'B'; all bar cut as 'AB' and all point cuts as 'AP'. The hanging coefficient (the ratio of the length of the rope to the stretched length of the netting) denoted as E.

4.3. Results and Discussion

Based on the study, the different harvesting gears like sluice net, gill net and cast nets observed were grouped taking into consideration of the size, type of material and method of operation. Handpicking of shrimps by men and women were recorded separately. Table. 4.1. gives the details of different fishing gears in traditional shrimp aquaculture.

4.3.1. Sluice net

Sluice net is a stationary conical shaped filtering device which is attached to a wooden or metal frame, fitted into slots on the sluice gate (Plate 4.1). The size of the net varies depending upon the size of the farm and sluice gate. It measures 5-9 m in length with varying mesh sizes ranging between 10 and 25 mm and is fixed to the mouth of the sluice gate by means of a rectangular frame. A number of rectangular panels go into the construction of the net. PA multifilament knotted or knotless twine of size 210x1x2 or PE twisted monofilament of diameter 0.75 to 1.5 mm is used. The nets are either fabricated by hand or by machine made webbings are used after shape and cutting.

Plate 4.1. Sluice gate for sluice net operations in shrimp filtration farm

Table 4.1. Details of different fishing gears in traditional shrimp aquaculture systems

Gear	Length of unit (m)	Depth of unit (m)	Mesh size (mm)	Material	Coefficient of hanging (E)	Float (material)	Sinker (material)
Gill net	30-50	2 –3	28-55	PA (mono filament)	0.5	PVC	Granite/ lead
	30-50	2 –3	28-32	PA (Multi filament)	0.5	PVC	Granite/ lead
Cast net stringed	-	2-3.5	20-32	PA (mono filament)	-	-	Granite/ lead
	-	2-3.5	20-32	PA (Multi filament)	-	-	Granite/ lead
Cast net stringless	-	2-2.5	20-32	PA (Multi filament)	-	-	Granite/ lead
Drag net (Large)	50-100	2-2.5	10-12	PA (Multi filament)	0.4-0.5	PVC	Lead
	50-100	2-2.5	10-12	PA (Multi filament)	0.4-0.5	PVC	Lead
Drag net (Small)	6-10	1-1.5	30-20	HDPE	0.5	-	-
Sluice net (Large)	-	-	10-15	PA (Multi filament)	0.5	-	-
Sluice net (Small)	-	-	10-15	HDPE	0.5	-	-

The mesh size ranges from 20 – 25 mm in the fore parts and progressively reduces to 10 mm in the codend region. Design and construction details of sluice nets of multifilament and monofilament material are given in Fig. 4.1. and Fig. 4.2. and the technical specifications are given in Table 4.2. Selvedge of half to two mesh depth of PA 210x2x3 is provided for strengthening the main webbing. It is hung on to a rope by reeving a number of meshes loosely in the four corners for strengthening the net. The main webbing and the selvedge are joined together with appropriate take up ratios. A hanging coefficient of 0.5 is given for mounting.

4.3.1.1. Operation

Filtration is carried out for 7-9 days in a fortnight *i.e.,* 3-4 days before or after full moon and new moon days either after dusk or before dawn as the shrimps are very active during this period. Maximum quantity of incoming spring tide water is kept inside the pond with the help of the shutter planks in the sluice gate. A light is installed near the inner mouth of the sluice gate to attract more shrimps. With the advent of electricity some farms have switched over to electric bulbs in place of the traditional kerosene lamps. During low tide when the water starts receding, the sluice net is fixed to the sluice gate and the shutter planks are removed. Water rushes into the net and the shrimps and fishes are filtered. A canoe is kept ready outside the sluice gate and is used for taking the catch from the codend. Coconut leaves are placed inside the canoe to prevent the shrimps from jumping out. The codend of the sluice net is secured in such a way that it can be opened very easily to empty the catch. A float is tied to the codend using a float line for facilitating easy retrieval of codend. As the catch in the codend

Table 4.2. Technical specifications of sluice net

	Small sluice net	Large sluice net
Main webbing	Polyamide	Polyethylene
Mesh size (mm)	15-20 mm	20-25 mm
Twine type	Multifilament	Multifilament
Twine specifications	210x1x2	0.75-1.5 mm Ø
Selvedge	210x2x3	1.5-2.0 mm Ø
Depth	3-5 m	5-9 m
Hanging coefficient (E)	0.5	0.5
Codend		
Mesh size (mm)	10 mm	10-12 mm
Twine type	Multifilament	Multifilament
Twine specifications	1.0 mm Ø	1.0 – 1.5 mm Ø
Depth	1.0 m	2-2.5 m
Ropes		
Material	Polypropylene	Polypropylene
Rope mouth region	2.5 – 3.0 mm Ø	2.5 – 6.0 mm Ø
Cod end rope	12 mm Ø	12-20 mm Ø
Float (attached to end of cod end)	Plastic can, float	Spherical PVC float
Float material	Plastic can or PVC	PVC
Floats per unit (No.)	1	1
Float size	100 – 150 mm	200 - 300 mm

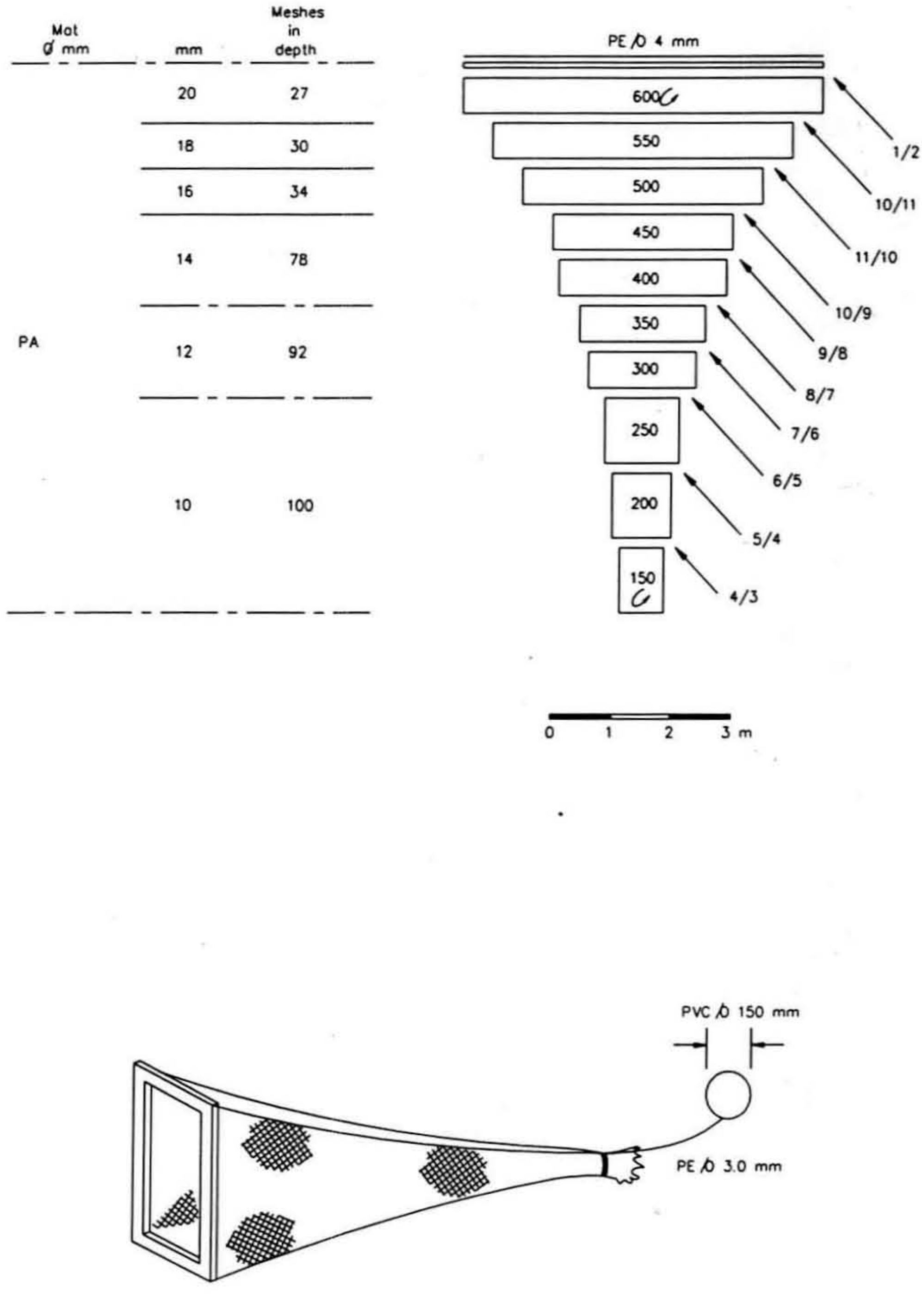
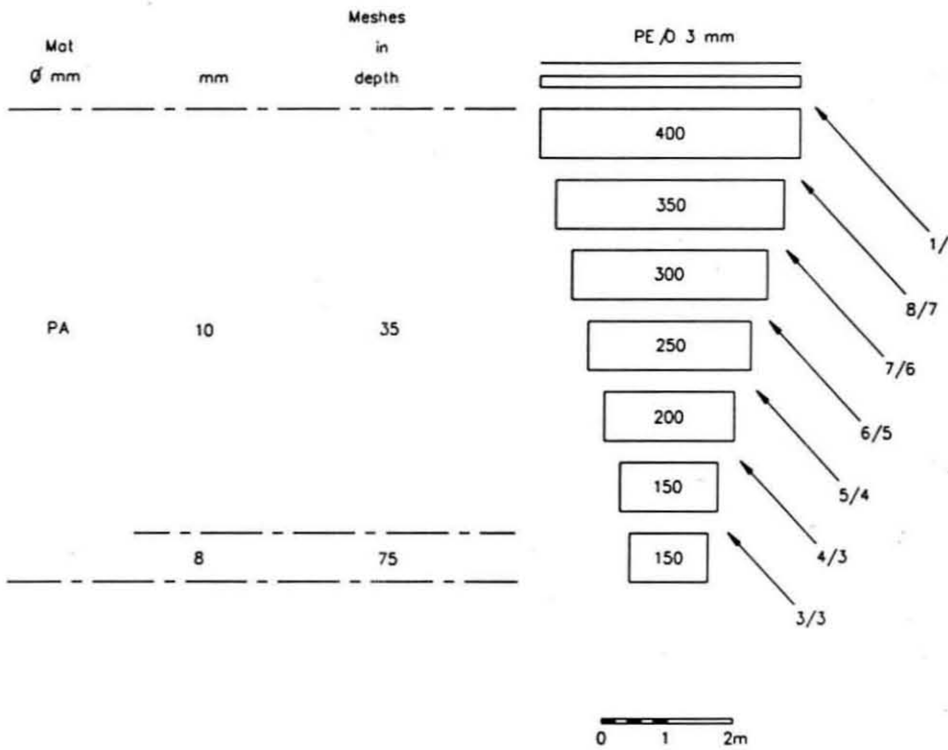


Fig. 4.1. Design of large sluice net



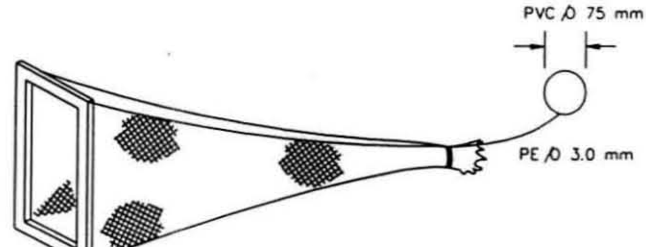


Fig. 4.2. Design of small sluice net

increases the float begins to sink and it is hauled up. The first haul is kept separately as it usually contains debris, clay and other waste materials. The net is operated for an average of 5 hours, till the ebb tide begins to slacken. Then the sluice gate shutters are closed.

The shrimps trapped at the codend of the net are removed periodically depending upon the catch in the codend to avoid overloading as this may crush and deteriorate the shrimp. Another alternative method is the suspension net (Fast, 1991). Lazy lines have been used for periodically hauling the codend of the net (De la Cruz, 1983) to reduce overloading.

Sluice nets are widely used in the paddy shrimp filtration fields (Panikkar, 1937; Kathirvel, 1978 and George *et al.,* 1968). Effluent gate with divided culvert having two bags for harvest is used in the US to continue harvest without interruptions (Villalon, 1991).

4.3.2. Gill nets

Design and construction details of a typical gill net of multifilament and monofilament netting materials are given in Fig. 4.3 & Fig. 4.4. respectively and the technical specifications in Table 4.3. The main netting is made of monofilament twine of size 0.16 mm or 0.20 mm are widely used. In the case of multifilament gill nets twine size 210x1x2 and 210x1x3 are used. Half mesh to two mesh depth selvedge made of 210x2x3 having a mesh size larger than the main webbing is provided both in the upper side (head rope) and lower side (foot rope) of the net. The upper selvedge is hung by reeving whereas the lower selvedge is stapled to the sinker line using PA 210x2x3 or 210x4x3 twine. The main webbing and the selvedge are laced together with a take up ratio of 2:1. Mesh size currently used in monofilament are 24, 26, 28, 30, 32, 34, 36 ,38, 40, 44, 48 and 52 mm and in multifilament same mesh sizes except 40 mm and above are used. Gill nets with mesh size ranging from 24-36 mm are generally used to harvest *P. indicus* and are locally known as *naran vala* whereas larger mesh size of 36 mm onwards are used to harvest *P. monodon* and are locally known as *Kara vala*. It has been observed that the large meshed gill nets are exclusively made of monofilament. The hanging coefficient provided has been 0.5 and has never exceeded 0.53.

Cylindrical PVC floats of diameter ranging from 50-60 mm and thickness ranging from 10 - 20 mm are used. The sinkers have been of granite stone or spindle shaped lead each weighing approximately 25 to 100 g which are used in the foot rope.

The present study indicated that gill nets are widely used in large traditional farms of Kerala. The gill nets operated in the aquaculture farms are similar in design to those used in the backwaters of Kerala.

4.3.2.1. Operation

Gill nets are operated as bottom drift by one or two persons from a wooden canoe of 4-6 m L_{OA}. The net is set either close to the shore or in the deeper regions of the pond. Unlike in the sea, the number of units operated per boat is restricted due to limitations in the size of the pond. The size of one unit is about 50 m in length and 2-3 m in depth. Only 4-5 units are operated by each canoe. The net is drifted for about 30 min to an hour. While hauling the net, both the head rope and foot rope are held together and are taken into the boat gradually by one person while the other manaeoeuvers the canoe. Coconut leaves or pieces of webbing are placed inside the canoe to prevent the shrimps from jumping back to the pond. Gill nets are used in the partial as well as final harvesting of the farm usually after dusk and before dawn during 7 days in each phase of the moon, *i.e.*, three days preceding and three days succeeding the full moon or new moon day as the case may be.

Table. 4.3. Technical specifications of shrimp gill nets

Main webbing	***PA monofilament***	***PA multifilament***
Mesh size (mm)	28 - 34	34-55
Twine type	PA multifilament	PA monofilament
Twine specifications	210x1x2 – 21x1x3	0.16 – 0.20 Ø
No of meshes in depth	100	50-60
Hanging coefficient (E)	0.5-0.53	0.5
No of meshes in length/unit	2000-3000	1500-2000
Hung length (m)	28-50	25-55
Hung depth (m)	2-3	2-3
Selvedge		
Mesh size (mm)	60-70	70-100
Twine type	PA multifilament	PA multifilament
Twine specifications	210x2x3	210x4x3
No of meshes in depth	2	0.5 –1
Ropes		
Material	Polypropylene	Polypropylene
Head rope dia (mm)	4-6	4-6
Foot rope dia (mm)	4-8	4-8
Floats and sinkers		
Float material	PVC	PVC
Floats per unit (No.)	40-50	30-40
Float size (mm)	50x10	60x20
Sinker material	Lead	Lead
Sinkers per unit (No.)	60-80	60-80
Sinker weight (g)	25	25

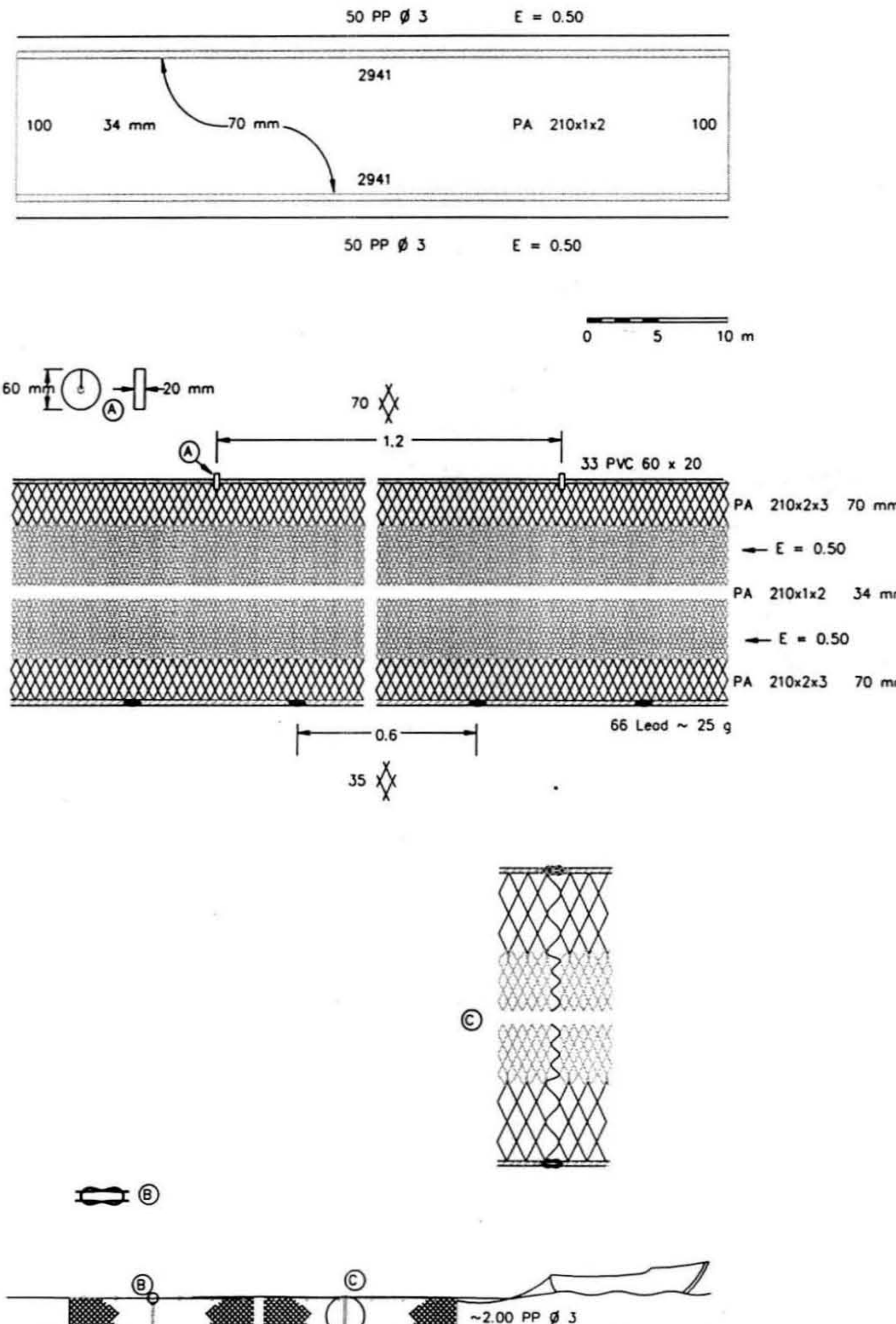


Fig. 4.3. Design of multifilament shrimp gill net

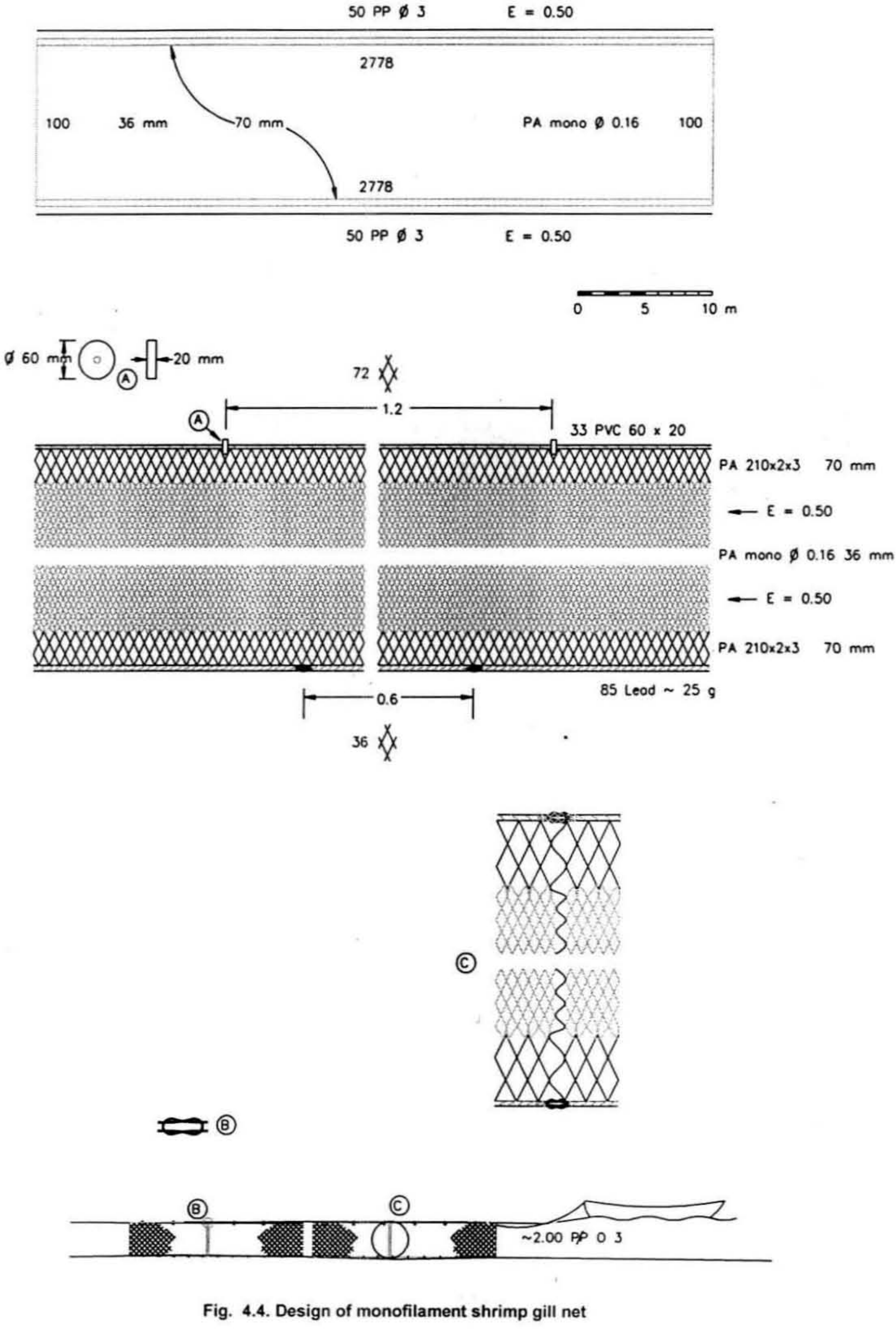


Fig. 4.4. Design of monofilament shrimp gill net

Gill nets are passive fishing gear and the fish gets gilled, wedged or entangled. In the case of shrimps, they are enmeshed in the net. Minor modifications to the gill net, *loop vala,* (Kurup and Samuel, 1983,1985; Pauly, 1991), *kandali vala* (Hornell, 1925, 1938) and *Kara vala* (Pauly, 1991) are operated for harvesting the shrimps in the culture farms. *Chemeen vala* (Kurien and Sebastian, 1986; George and Brandt, 1975; Pauly, 1991; Thomas, 2001) are used extensively in the shrimp culture farms. The farmers have shifted from multifilament twine material to monofilament. This trend was also observed in the marine sector (Thomas, 2001).

4.3.3. Cast net

Cast nets or falling nets, as the name implies are thrown over the water surface where catch is expected (Plate 4.2. & 4.3). It is perhaps the oldest and the most simple method for partial harvest in aquaculture systems. Two types of cast nets (stringed and stringless) types are operated in the aquaculture systems. These have a central line for hauling the net. In the case of stringed variety, the central line branches out into several strings before reaching the outer margin of the net, so that pockets are formed at margin when the net is pulled together and hauled up (Fig. 4.5.). In the latter, the pockets are fixed by turning over the lower end meshes and fastening it by twines. There is no connection between the central line and these pockets (Fig. 4.6.). These nets are observed to be more prevalent in aquaculture farms of northern Kerala. Cast net with fixed pockets are especially used in shallow water, free of obstacles.

Design and construction details of cast nets of multifilament and monofilament cast nets are given in Fig. 4.7. and Fig. 4.8. and the technical specifications are given in Table 4.4. As in the case of gill nets, the farmers have taken preference to monofilament over multifilament material for cast nets. The main webbings are made of 0.16 , 0.20 and 0.23 mm diameter in the case of monofilament twine and in the case of

Plate 4.2. A large cast net spread for drying

Plate 4.3. A large cast net cast from a canoe

Table 4.4. Technical specifications of shrimp cast nets

Main webbing	*Multifilament*	*Monofilament*
Mesh size (mm)	20 - 32	20-32
Material	PA multifilament	PA monofilament
Twine specifications	210x1x2 , 210x1x3	0.16, 0.20, 0.23 Ø
Length (m)	2.5-3	3-5
No of meshes in top	150-175	175-275
No of meshes in bottom	1500-2500	2000-3000
Bottom radius (m)	2-2.5	2.5 – 4
Selvedge		
Mesh size (mm)	30-40	30-40
Material	PA multifilament	PA multifilament
Twine specifications	210x1x3 210x2x3 210x6x3	210x2x3 210x6x3 210x9x3
Ropes		
Main rope		
Material	PP multifilament	PP multifilament
Twine size (mm)	4 Ø	4 Ø
Foot rope (double)		
Material	PA multifilament	PA multifilament
Twine size	210x4x3	210x6x3
Sinkers		
Material	Lead	Lead
Shape	Spindle	Spindle
No. per unit	60-80	60-80
Weight (g)	20	20-25

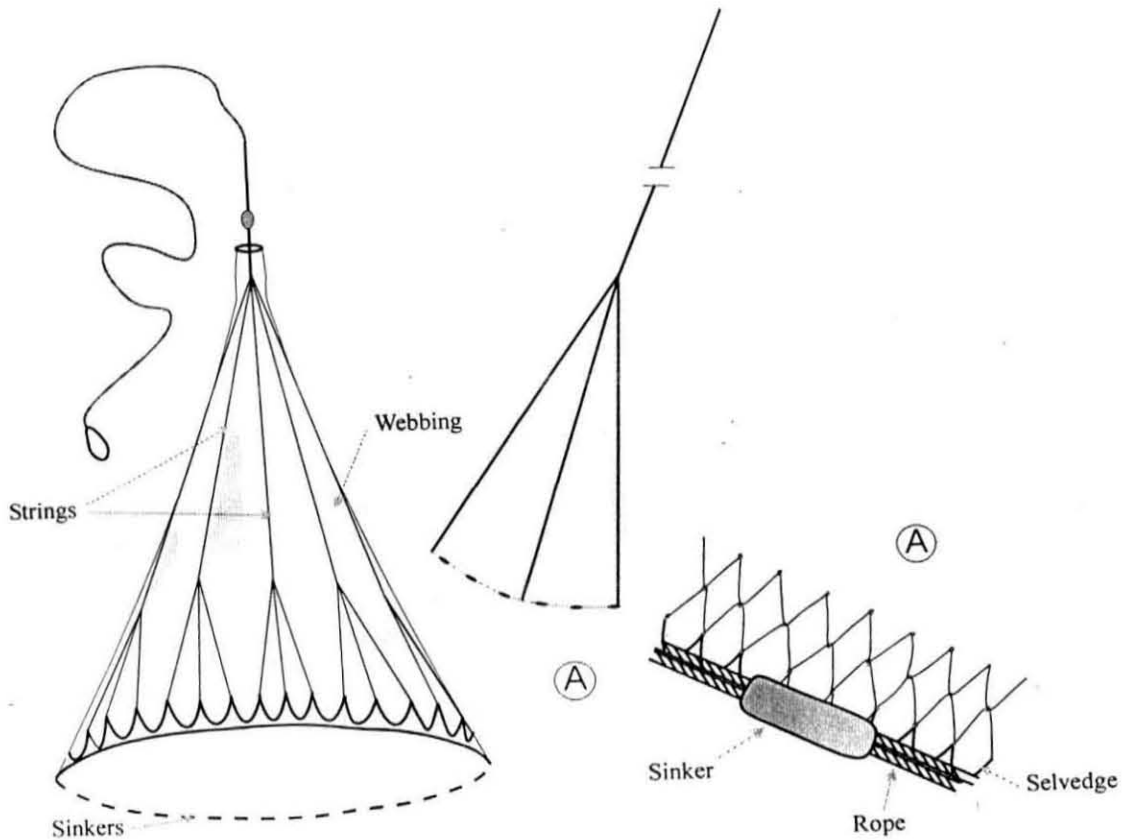


Fig. 4.5. Stringed cast net

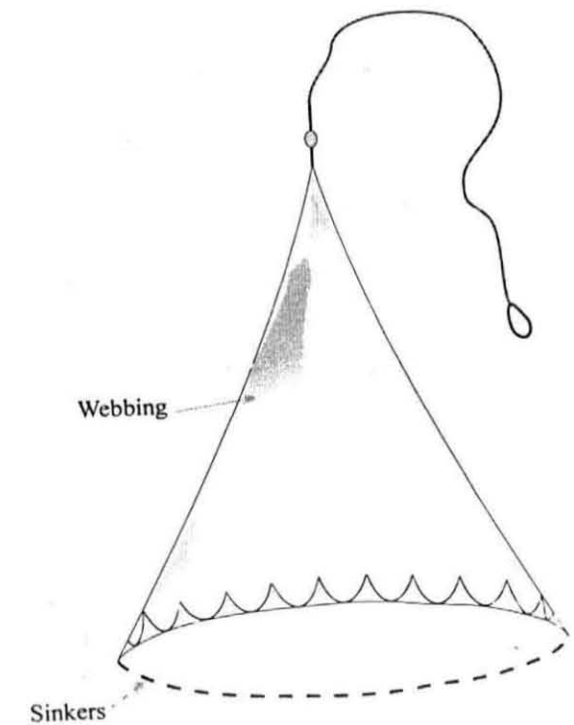


Fig. 4.6. Stringless cast net

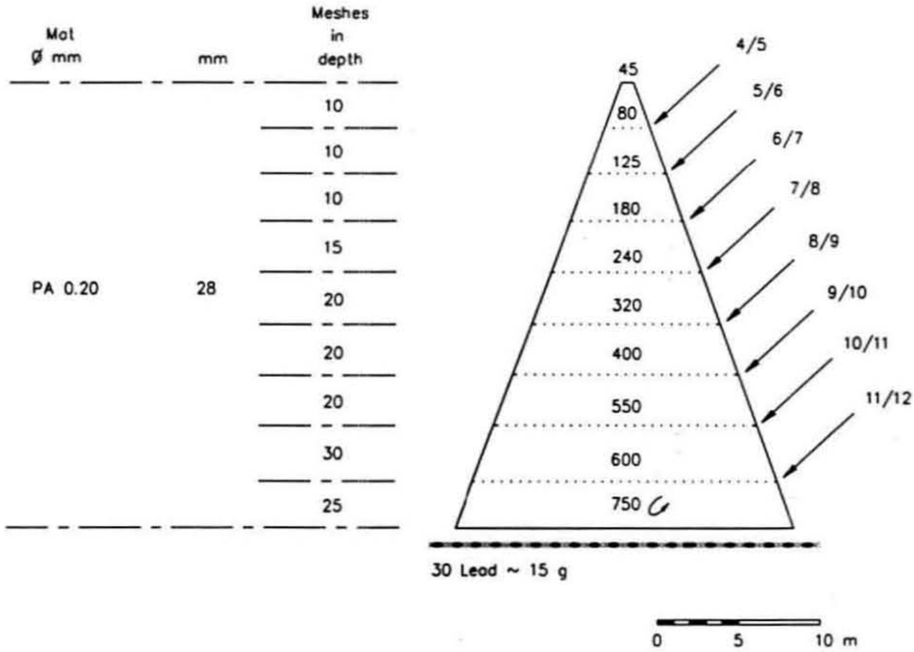


Fig. 4.7. Design of shrimp cast net (stringless)

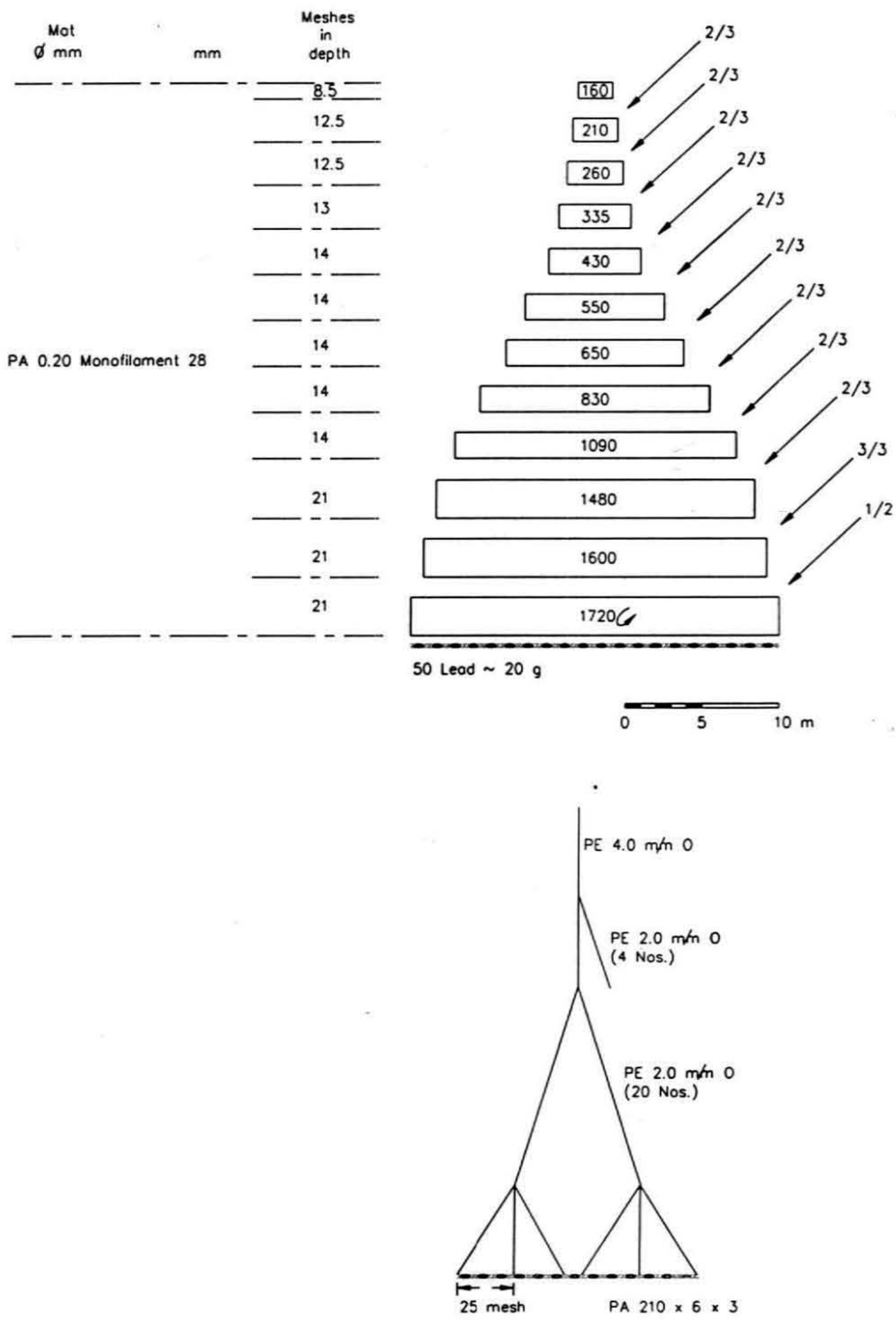


Fig. 4.8. Design of shrimp cast net (stringed)

multifilament 210x1x2 and 210x1x3 are used. The size of the cast net ranges from 2.5 to 5 m in depth and from 8-12 m in the circumference of the net. The net is either hand made or machine made of PA 210x1x2 or 210x1x3. In the case of hand braiding, the net is brought to shape by either baiting or creasing at appropriate intervals. In case of machine webbing where ready made pieces are obtained the webbings are joined together following appropriate take up ratios. Half mesh to one mesh depth selvedge made of PA twine of 210x2x3 to 210x6x3 having a mesh size larger than the main webbing is provided both in the anterior and posterior end of the cast net. The selvedge in top portion of the net is fixed to a metal ring sinkers (lead) are attached to the bottom selvedge of the net. In the case of stringed cast nets, the main string which is held by hand is made of 4 mm diameter PP material. It branches into four or six strings and then each string is further divided into three or four strings which is attached to the bottom portion of the net where sinkers are attached. These strings are made up of PA multifilament twines of varying sizes depending upon the size of the cast net. Mesh sizes currently used in monofilament and multifilament cast nets are 20, 24, 26, 28, 30, and 32 mm, the most popular being 26 mm for capture of shrimps. A few cast nets are constructed using a combination of monofilament and multifilament material. Usually the upper portion of the net is made of multifilament and the lower portion of the net is made of monofilament webbing. Cast nets are also grouped separately for fish and shrimps. The cast nets used for fish have much larger mesh size compared to the shrimp cast nets. There are also nets for harvesting *P. monodon* (Tiger shrimp) called *Kara veesu vala* and for *P. indicus* (White shrimp) known as *Naran veesu vala*. Again here, the main difference between them is the mesh size. 26 – 30 mm mesh size are popular for *P. indicus* and larger mesh size of 30-50 mm are used for *P. monodon*. The present study shows that cast nets are very popular among the aquaculture farmers and are widely used in all the farms. The design specifications do not vary much and are very much similar to the cast nets operated in the sea except that the size of the net used in the marine sector is bigger.

4.3.3.1. Operation

Usually two persons are associated with the operation of the gear. The gear is cast by one man and the other helps in collecting the catch and clearing the net from debris before the next throw. The net remains immersed in water for two to three minutes and is then slowly hauled up. Some farmers operate cast nets after placing feed and others use lights in certain areas of the pond to attract, gather and concentrate the shrimps in one region. These nets are cast with great skill in order to fall flat so as to cover the maximum area upon the water surface either from the shore or from a canoe. It sinks under the influence of weights secured to the outer lower periphery of the net and the shrimps or fish beneath the net are trapped. When it is hauled in, the weights converge towards one another and the catch is trapped. The catch entangled in the net are removed and kept in a basket.

Cast nets are also used to take samples from the pond to estimate the approximate total yield from the pond. Use of cast nets in aquaculture farms has been reported by (Kathirvel, 1978; Unnithan, 1985; Purushan, 1995; SEAFDEC, 1986; and Agrawal, 1999). Fast (1991) observed that In aquaculture, cast netting was not very efficient in terms of kg harvested per man hour, but it could be cost effective where labour is inexpensive. Cast net up to a circumference of 12 m were observed in the aquaculture farms. There are much larger nets with circumference of 20 m and more prevalent in the marine sector (Hickling, 1961). Though there were no changes in the traditional design, the fishermen have tried variations in the use of materials by fabricating the upper portion of the cast net with multifilament which they feel facilitates easy handling and holding the net for casting and the lower part with monofilament to increase the catching efficiency of the net. The fishermen especially from south India operate the cast net from a canoe with great skill. This has also been acknowledged by

Brandt (1972). The use of bait, lures or attracting devices like light are used in some farms which can increase the handling and catching efficiency of cast net. Coconut wastes are used to attract the shrimp before the net is cast from boats (Suseelan, 1975).

4.3.4. Seine net

Seine nets are also used for either partial or final harvest of shrimp from aquaculture ponds. The level of water inside the pond is lowered before seining. Seining is more successful when the water level is lowered so that the shrimp are confined to the canals (Menasveta and Higuchi, 1983; Anon, 1984; Unnithan , 1985).

PA knotted or knotless webbing of twine size of 210x2x3 – 210x6x3 with mesh size of 10 mm is used for the main piece. A half mesh selvedge made of twine size 210x9x3 with mesh size 60 mm is given. The technical specifications of the a typical drag net are given in Table 4.5. PP rope of 24 mm diameter is used for the head rope and foot rope. The sinker and floats are attached using a PP rope of 3 mm diameter. The main webbing and the selvedge are laced together with a take up ratio of 6:1. The hanging coefficient provided is generally 0.5. The length of the net is about 180 m and the depth is 2.5 m. The length is usually about one and half times the width of the pond and the depth about two to three times the depth of the pond. The mesh size of the net depends on the size of the animal to be harvested.

PVC floats, of diameter 50 mm and thickness 20 mm are fixed on the head rope at an interval of 30 cm. Lead sinker each weighing approximately 100 g is fixed on the foot rope at 1m interval.

Table 4.5. Technical specifications of drag net

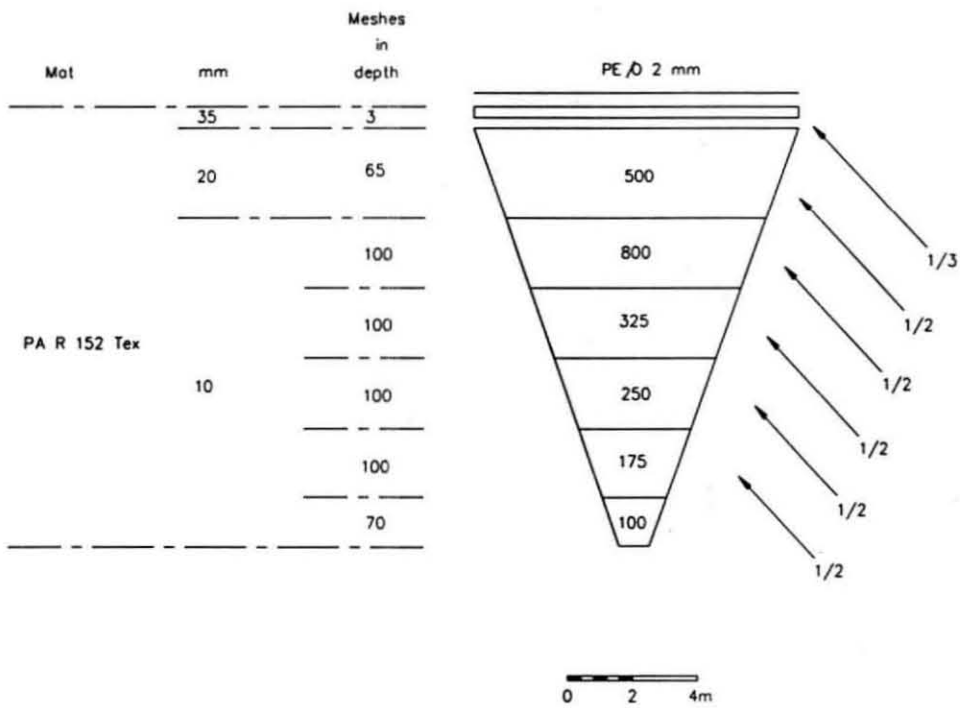
Main webbing	Small drag net	Large drag net
Mesh size (mm)	10 mm	10 mm
Material	PA multifilament	PA multifilament
Twine size	210x4x3	210x6x3
No of meshes in depth	100-150	200-250
Hanging coefficient (E)	0.5	0.5
Hung length (m)	50-60	150-180
Hung depth (m)	1.5-2.0	2.5
Codend		
Mesh size (mm)	10	10
Material	PA multifilament	PA multifilament
Twine size	210x6x3	210x9x3
Ropes		
Material	Polypropylene	Polypropylene
Head rope dia (mm)	12-14	24
Foot rope dia (mm)	12-14	24
Float		
Float material	PVC	PVC
Floats (No.)	200-250	500-550
Float size (mm)	50x10	50x20
Sinker		
Material	Lead	Lead
Number per unit	100-120	150-180
Weight (g)	100 g	100g

4.3.4.1. Operation

The water level in the pond is lowered and the drag net is dragged slowly from one end of the pond to the other end. Eight to ten persons are required for the operation. The foot rope touches the bottom of the pond when the net is dragged. One or two persons follow the net from behind to clear the entanglement of the gear with the bottom mud. Both ends of the net are brought closer and the catch is collected with the help of scoop net and later picked by hand. Mechanized seine nets which are more efficient are also used for harvesting shrimps (Williamson and Wong, 1982 and Losordo *et al.*, 1986). A corralling method of seining is used in Ecuador, where two seines are drawn towards each other from opposite ends of the pond (Reisinger, 1985). However, seining is not a preferred method as mud and detritus are often mixed with the shrimp and often the shrimps are damaged. The unevenness of the pond bottom also makes seining difficult in most shrimp farms.

4.3.5. Drag net

Small drag net commonly known as *vadi vala* or *koruvala* is also popular for harvesting shrimps in the aquaculture farms among the shrimp farmers in Kerala (Fig. 4.9). Use of this net in the shallow backwaters has been reported (Ramamurthy and Muthu, 1969 and Kurien and Sebastian, 1986) This net is bag shaped and has a fixed mouth opening of about 4x1 m and is about 6 m long. Wooden sticks or bamboo poles of 1.2 m are fixed on both ends of the webbing for holding, pulling and keeping the mouth of the net open. The main webbing is either made of knotted or knotless PA multifilament or PP twisted monofilament of size 210x1x2 or 0.75-1.0 mm diameter with a mesh size of 20 mm in the fore part decreasing to 10 mm in the hind part. Selvedge of three meshes depth of 35 mm is provided for



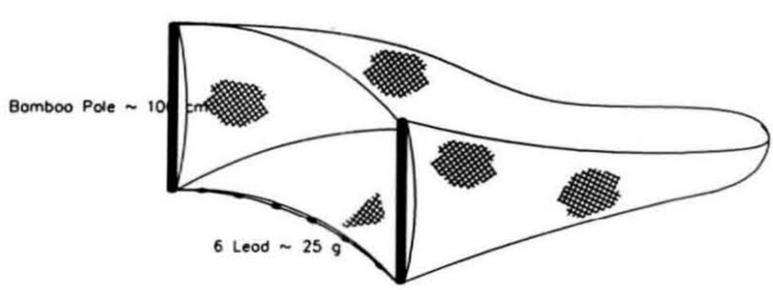


Fig. 4.9. Design of drag net

mounting the main webbing to a PE twine of 3.0 mm diameter which is attached to the bamboo pole.

4.3.5.1. Operation

Three persons are required to operate the net. Two persons hold the bamboo poles and drag the net along the bottom of the pond. The third person helps in collecting the shrimps after the net reaches the shore. The operation is repeated several times covering the whole area of the pond. This net is used in the final harvesting operations.

4.3.6. Aerial traps

This is a fishing technique based on the shrimp's reflex action to physical stimulation and is being used for harvesting the shrimps in perennial aquaculture farms in Kerala. They are locally known as *Pachil Changadom or Changala Pachil.* It is an interesting method for capturing shrimps. Use of this method in shallow waters in canals and backwaters and large aquaculture ponds has been reported by Panikkar (1937); Hornell (1938); Gopinath (1953); Job and Pantulu (1953); Kurien and Sebastian (1986) and George (1991). The shrimps, when disturbed, jump by reflex action and this habit is exploited for this type of fishing. It is also known as *Pran-Junkhar* or *Pachil* locally.

4.3.6.1. Operation

Two medium size canoes are tilted towards inside and connected with bamboo poles at the anterior and posterior extremities. The distance between the two canoes is 1 m. Weights are kept inside the canoe so that the edges will be very near to the water surface. A long heavy iron chain is attached to the bows of the two canoes and is dragged along the bottom. The middle region of the chain lies in the water touching the ground. The boats are moved forward by means of poles or oars. When the chain disturbs the bottom, the shrimps jump out of the water and fall into the canoes. Inside the canoe twigs and leaves are kept to prevent the escape of shrimps landing inside the canoes. It is usually operated at night. To attract the shrimps a kerosene lamp is also placed in the boat. This practice is not so popular nowadays and is rarely seen.

4.3.7. Cover pots

Cover pots or plunge baskets, locally known as *Ottals* in Kerala are simple devices used in backwaters, paddy fields and estuaries (Hornell, 1938). It is a conical basket open at both ends and made of bamboo strips or cane, laced together by coir ropes. The opening at the top is around 15 cm in diameter and at the bottom 50 cm in diameter. The height ranges between 45 cm to 60 cm. The ends of the strips at wide opening is sharp for pushing it into the mud.

4.3.7.1. Operation

The gear is operated during low tide by a single person. Both men and women operate this gear The trap is plunged into the water where shrimps are likely to be present and firmly pressed down. The disturbance in the water and also the sound of shrimps hitting the basket from inside indicate that shrimps are caught. They are then taken out by hand through the top opening. Kurien and Sebastian, (1986) have also described its operation in backwaters and shallow water bodies. A basket is also carried with the person to keep the harvested catch. It is used mostly during the final harvesting. The shrimp inside are searched out by putting one hand through the top opening .

The visceral mass of the snail is used as bait and is tied to a piece of strong string and at the opposite side a small float is tied. Several of these are kept in waters in a small area where shrimps are abundant. When the shrimps nibble at the food tied to the string the float jerks and the shrimps are entrapped by using cover baskets.

4.3.8. Hand picking

Harvesting of shrimps using bare hands has been observed in all the shrimp farms. It is the simplest form of fishing since ancient times and commonly seen in the estuaries and backwaters of Asian countries (Gudger, 1952). It is also carried out in the paddy fields and shallow beaches in India (George *et al.*, 1968; Pai *et al.*, 1982; Unnithan, 1985). It is locally called as *Thappal.* It was observed that practice of hand picking of shrimps and other fishes was mainly dominated by skilled fisherwomen.

4.3.8.1. Operation

The operation starts early in the morning and continues till evening. The level of water in the pond is usually reduced to the minimum possible extent. The fishers stand in a row at one end of the pond and gradually move towards the opposite end of the pond covering the entire stretch. They again return and also move in the pond in a zig zag motion to cover maximum area of bottom of the pond. The bottom of the pond is searched by the fishers with the feet or hands for any fish or prawn. As they advance, any shrimp or fish that are felt by the foot are taken by hand. Skilled women fishers carry out this type of fishing even in neck deep waters for shrimps. The catch is collected in a floating pot which is carried along with them. (Plate 4.4.) This type of fishing method is locally called *Kalakippiditham, Chavuttuppiditham, Thappiyedukkal* and *Veetiyedukkal.* in Kerala (Kurup *et al.*, 1993).

Plate 4.4. Hand picking of shrimps by fishers

4.3.9. Other methods

4.3.9.1. Kolanjil katti vala

This method is mostly seen in the northern parts of Kerala. Coconut florescence stalk locally called *Kolanjil* are tied to a 20 mm diameter PP rope of length 20-30 m and is fixed at an interval of about 1 m. A granite stone weighing about 5 kg is fixed in between as shown in Fig. 4.10.(a) or galvanized iron chain links are tied as shown in Fig. 4.10.(b).

4.3.9.1.1. Operation

The ropes at each end of the tackle is held and dragged from one end of the pond to the other end by 5-6 persons. Operation is usually done only after lowering the water level and is used in the final harvest. During dragging the weights attached to the rope keeps the whole gear system submerged under water and the uneven sharp edges of the *Kolangil* disturbs the pond bottom. Any shrimp buried in the mud is forced to come out and move towards the bank. The shrimps are harvested using a cast net or scoop net or by hand picking. Similar version of operation is also being carried out in seasonal shrimp farms in Vypeen and are locally known as *Kodha pottikunu or changla vala.* Instead of granite stones, 10 mm diameter GI chains are used and tied along the rope. The method of operation is the same.

4.3.9.2. Scoop nets

Scoop net resembles a large spoon and is operated by one fisherman. Scoop nets are made by bending a bamboo pole like a 'U' and the

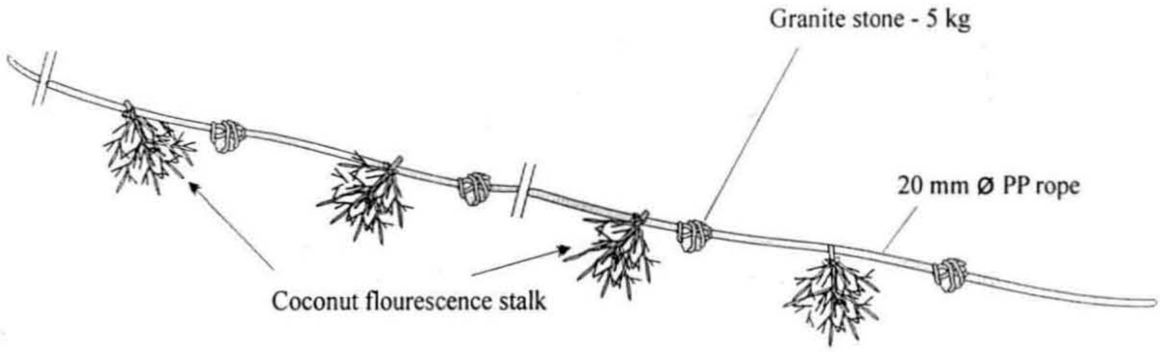


Fig. 4.10 (a) Arrangement of coconut fluorescence stalk and granite stones for harvesting shrimps

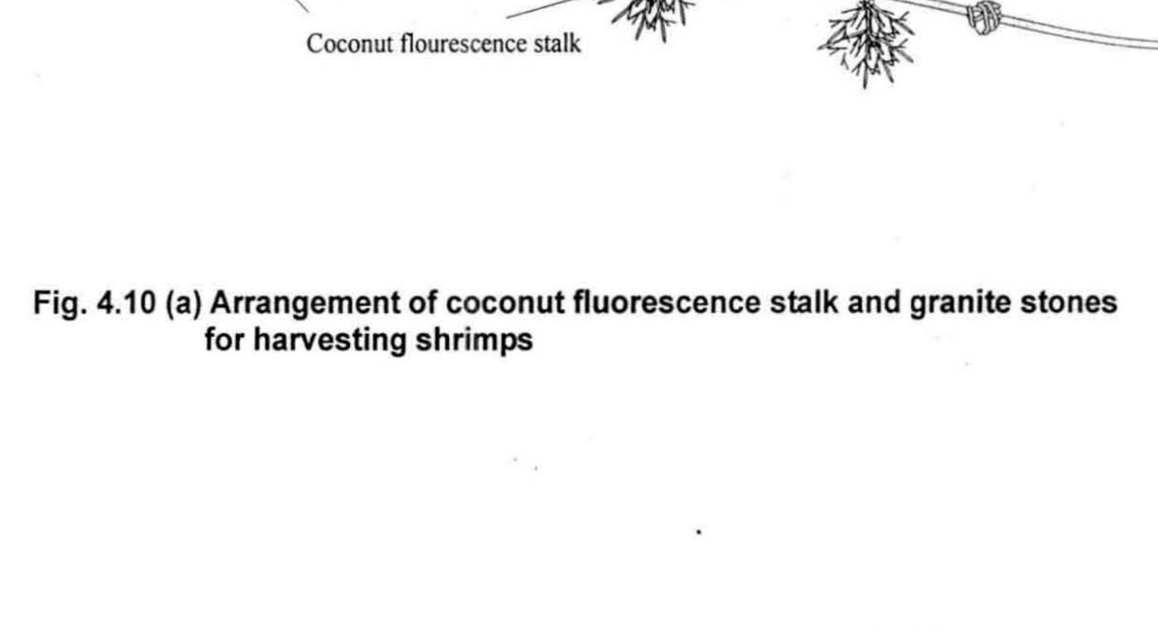


Fig. 4.10 (b) Arrangement of coconut fluorescence stalk and link chains for harvesting shrimps

free ends are tied with a thick rope. A netting of 6 mm to 12 mm mesh is fixed on this frame which remains bag like.

4.3.9.2.1.Operation

One man holds the frame on either side and makes through shallow water to catch shrimps. The shrimp or fish is filtered when the scoop net is lifted from the water. Scoop nets are known as *Vattuvala* or *Arippuvala* in Kerala. Scoop nets are also operated in Thailand for shrimps and other fishes (SEAFDEC, 1986) and in Sumatra, Indonesia, (Pajot, 1989).

4.3.9.3. Stupefying

Insecticides, pesticides or chemicals are usually used in shrimp aquaculture farms in Kerala for harvesting the shrimps. It is carried out in the final stages of harvesting in most of the seasonal shrimp aquaculture farms. As poisoning is an illegal practice (Anon, 1980), it is done secretly during night. This practice is mostly carried out in the leased ponds as a last resort to capture all the shrimps available in the farm before completion of the lease period.

4.3.9.3.1. Operation

Benzene hexachloride BHC and dichloro diphenyl trichloroethane (DDT) powder is mixed with other insecticides and sand. This mixture is added into the pond carefully as overdose may kill all the shrimps and fish in the pond. This mixture is distributed evenly in the water near the pond edges opposite to the sluice gate at night keeping the level of the water as low as possible. The shrimps avoid the poisoned areas and try to move in the opposite direction towards the sluice gate. At high tide, freshwater is allowed inside and all the shrimps rush towards the sluice gate. When the tide recedes the sluice gate is opened and the shrimps escape from the uncomfortable environment and are trapped in the sluice net. This procedure is repeated with a higher dosage of chemicals on the next day. This has been found very effective for *P. indicus* as they seem to be more sensitive and most of them move out of the pond. But *P. monodon* is not easily flushed out and has to be harvested using cast nets and hand picking.

4.3.9.4. Warming of water

During the final stages of harvesting the water level inside the pond is kept at a bare minimum level and is allowed to get heated naturally by the sun. As the water level is low the water gets warmed and the shrimps are forced to move towards deeper areas of the pond where it is comparatively cooler. During high tide, water enters inside through the sluice gate and the shrimps move towards the entrance which is much cooler. They are caught in the sluice net when the tide recedes again. This practice is being carried out by most of the seasonal farmers as the depth of the pond is usually low as compared to the perennial farms. This technique is repeatedly done during the end of the season to harvest as many shrimps as possible.

Different harvesting techniques are used for harvest of shrimps from filtration farms. Operation of sluice net is the most common practice used for harvesting shrimps from these farms. Gill net and cast net are used periodically in the perennial farms where as it is used only during the final phase of harvesting in seasonal farms. Other methods like hand picking, warming of the water, use of chemicals, draining of water etc., are carried out at the end of the lease period. Though, harvesting of shrimp by poisoning the water is illegal the practise is still being carried out clandestinely in the prawn filtration farms as the owner of the farm wants to harvest all the shrimps before the completion of the lease period.

CHAPTER - 5

PRODUCTIVITY AND INTENSITY OF OPERATION OF GEAR SYSTEMS

5. PRODUCTIVITY AND INTENSITY OF OPERATION OF GEAR SYSTEMS

5.1. Introduction

Trapping and holding shrimp and fish seeds into the seasonal *(pokkali)* and perennial fields through tidal influx is a traditional culture method practised in Kerala. Normally, each field is provided with at least one sluice gate which opens into the backwaters. The size of the sluice gate varies according to the area of the field. Adjustments of wooden shutter's planks at the mouth of the sluice gate regulate the flow of water. The stocking of the seeds is accomplished by the seed brought in by the incoming tides. Water is let in during high tide and let out during low tide keeping closely packed bamboo screen at the mouth of the sluice gate to prevent the escape of shrimp fry. The seeds thus entering into the field are allowed to grow for a short period by feeding on the natural food available and the stock is harvested periodically through sluice gate filtration and other fishing methods like gill net, cast net, drag net and hand picking. Preliminary study to assess the yield from paddy fields and the rate of growth of the different shrimp species has been carried out by many workers (Panikkar, 1937; Menon, 1954, Gopinath, 1956; Panikkar and Menon, 1956; Kestaven and Job, 1957; Raman and Menon, 1963; George *et al.*, 1968; George *et al.*, 1974, George and Brandt, 1975; Gopalan *et al.*, 1982; Verghese *et al.*, 1982; Jose *et al.*, 1987; Mathew and George, 1987; Kurup *et al.*, 1992; Mathew, 1993; Pillai and Krishnan, 1998; Chandramohan *et al.*, 1999; Purushan, 1995, 1996 a, b, and c, 1989; Unnithan, 1985, 2000; and Srinath *et al.*, 2000). However, the productivity and intensity of operation of different gears have not been worked out.

Harvesting is done mostly over a period of seven or eight nights, distributed on either side of the full moon and new moon days. In the case of perennial farms, in addition to the above, total harvest is carried out once in three months using different fishing gears. The present study was undertaken to study the gear-wise intensity of operation and productivity of the different harvesting systems employed in extensive traditional shrimp culture systems.

5.2. Materials and Methods

Six seasonal fields and six perennial fields in Vypeen island (Ernakulam district, Kerala) were selected for the study. Fortnightly sampling of catch was taken from the sluice nets during each lunar phase for a period of 18 months from December 1999 to April 2001. The individual length and weight of shrimp caught were recorded separately and compared to assess the difference in length classes and catch of different species of shrimps landed in the respective gear. Random samples from the total catch were taken when the catch obtained was more than 1 kg, otherwise, the whole catch caught by the net was used for analysis. The catch samples taken from the selected nets were sorted species-wise and sex-wise for studying the resource specificity and productivity of the gear used for harvesting shrimps. Samples were collected from cast nets and gill nets from perennial farms during periodic harvesting which is usually done once in three months. Catch data on hand picking were also collected from these farms whenever it was being carried out. The shrimp production from each farm by different gears was estimated based on 10 % random sample in the case of cast net and gill net and for handpicking and sluice net total landings of the gear were collected separately for each farm. Details were also collected from the register maintained separately for this purpose by the lessee of the respective farms. In the case of gill net the total catch is presented as catch (kg) obtained per 1000 m^2 of netting per hour (kg.1000 $m^2.h^{-1}$ and in kg.ha^{-1}), cast net (kg. cast h^{-1} and kg.ha^{-1}), bag net (kg.h^{-1} and kg.ha^{-1}) and in the case of hand picking it is given in catch in kg.h^{-1}person^{-1}. Month-wise, season-wise and species-wise total catch and average yield from each farm and contribution of each gear in the total catch were also calculated.

5.3. Results and Discussion

5.3.1. Gear-wise intensity of operation and yield

Monthly gear-wise intensity of operation and total production from different harvesting methods from seasonal farms and perennial farms are given in Table 5.1. & 5.2. respectively.

5.3.1.1. Seasonal farms

The average production from all the gear for seasonal farm was 408.1 $kg.ha^{-1}$ during 1999-2000 and it reduced to 384 $kg.ha^{-1}$during 2000-2001. This was mainly due to disease outbreak in a few of the seasonal farms in Vypeen during the period.

Sluice net : Sluice nets were operated throughout the season from December to April every year. The average production of shrimps from sluice net in the seasonal farm, varied from 25.9 $kg.operation^{-1}$ to 103.9 $kg.operation^{-1}$ during 1999-2000 whereas it varied from 22.9 $kg.operation^{-1}$ to 85.7 $kg.operation^{-1}$ during 2000-01. The highest production was recorded during February and its magnitude fluctuated during different months, lowest being in December and April in both the years. The rate of production of shrimps varied from 363.5 $kg.ha^{-1}$ to 377.91 $kg.ha^{-1}$, in the two seasons.

Gill net : Gill nets were operated only during the end of the season during February and March. The average production of shrimps from gill net varied from 1.85 $kg.1000\ m^{-2}.\ h^{-1}$ to 2.83 $kg.1000\ m^{-2}.h^{-1}$. The highest production was recorded during March. The rate of production of shrimps from gill net was 10.14 $kg.ha^{-1}$ in 1999-2000 and it increased to 11.38 $kg.ha^{-1}$ in 2000-01.

Cast net: Cast nets were also operated only during the end of the season. The average production of shrimps from cast net varied from 1.54 $kg.unit^{-1}$ to 1.62 $kg.unit^{-1}$ during 1999-2000 and 2000-01, respectively. The highest production was recorded during March in both the seasons.

Table 5.1. Gear-wise intensity of operation and total production from seasonal farms

Harveting method	SLUICE NET			GILL NET			CAST NET			HAND PICKING			GRAND TOTAL (kg.ha^{-1})
Units	No. of Operations	Production operation^{-1}	Total (kg.ha^{-1})	No. of Units	(kg.1000 m^{2})	Total (kg.ha^{-1})	No. of Units	(kg/unit)	Total (kg.ha^{-1})	No. of Persons	(kg. person^{-1})	Total (kg.ha^{-1})	
Dec-99	21	28.24	11.51	0	-	0.00	-	-	0.00	-	-	0.0	11.5
Jan-00	60	46.03	53.63	0	-	0.00	-	-	0.00	-	-	0.0	53.6
Feb-00	80	103.91	161.42	50	2.920	3.20		-	0.00	-	-	0.0	164.6
Mar-00	106	65.24	134.27	109	2.820	6.93	33	1.700	2.73	256	2.431	12.1	156.0
Apr-00	34	25.85	17.07	0	-	0.00	7	1.400	0.30	77	3.292	4.9	22.3
Total	**301**	**64.66**	**377.90**	**159**	**2.83**	**10.14**	**40**	**1.54**	**3.03**	**333**	**5.72**	**17.0**	**408.1**
Dec-00	25	25.20	12.23	-	-	0.00	-	-	0.00	-	-	0.0	12.2
Jan-01	83	37.66	60.70	-	-	0.00	-	-	0.00	-	-	0.0	60.7
Feb-01	91	85.65	151.34	45	1.390	1.24	7	1.600	0.48	38	1.895	1.4	154.5
Mar-01	105	64.81	132.14	155	2.100	10.14	24	1.620	1.49	217	1.369	5.8	149.5
Apr-01	16	22.88	7.11	-	-	0.00	-	-	0.00	-	-	0.0	7.1
Total	**320**	**58.50**	**363.51**	**200**	**1.85**	**11.38**	**31**	**1.62**	**1.96**	**255**	**3.26**	**7.2**	**384.0**

Table 5.2. Gear-wise intensity of operation and total production from perennial farms

Harveting method	SLUICE NET			GILL NET			CAST NET			HAND PICKING			GRAND TOTAL (kg.ha^{-1})
Units	No. of Operations	Production operation^{-1}	Total (kg.ha^{-1})	No. of Units	(kg.1000 m^{-2})	Total (kg.ha^{-1})	No. of Units	(kg.unit^{-1})	Total (kg.ha^{-1})	No. of Persons	(kg. person^{-1})	Total (kg.ha^{-1})	
Nov-99	24	32.33	5.37	0	-	-	-	-	-	-	-	-	5.37
Dec-99	48	44.30	15.42	0	-	-	-	-	-	-	-	-	15.42
Jan-00	48	61.90	22.62	105	3.20	1.12	0	-	-	-	-	-	23.74
Feb-00	48	76.10	28.38	363	2.78	11.84	197	3.57	5.6	-	-	-	45.78
Mar-00	48	44.32	17.64	69	3.93	1.04	38	3.61	1.0	-	-	-	19.73
Apr-00	48	35.40	13.10	252	2.63	6.98	198	3.70	5.8	-	-	-	25.85
May-00	48	35.32	13.02	253	3.39	11.62	321	3.75	9.3	-	-	-	33.90
Jun-00	48	78.88	29.08	117	3.38	4.65	114	4.73	4.2	-	-	-	37.91
Jul-00	48	51.51	18.99	60	2.01	0.88	0	-	-	145	1.33	1.5	21.35
Aug-00	48	44.62	16.45	0	-	0.00	10	1.82	0.1	897	1.69	11.6	28.21
Sep-00	48	14.44	5.32	52	2.75	0.66	43	1.50	0.5	-	-	-	6.48
Oct-00	48	10.40	3.83	60	0.47	0.35	27	1.23	0.3	-	-	-	4.43
Total	**552**	**44.638**	**189.25**	**1331**	**3.38**	**39.1**	**948**	**3.621**	**26.7**	**1042**	**1.637**	**13.1**	**268.2**
Nov-00	24	41.75	7.70	18	1.03	0.18	0	-	0.0	-	-	0.0	7.88
Dec-00	48	35.37	13.04	20	3.64	0.41	4	12.250	0.4	-	-	0.0	13.82
Jan-01	48	41.78	15.40	44	2.52	0.81	41	3.534	1.1	-	-	0.0	17.32
Feb-01	48	64.39	23.74	210	3.42	7.50	147	4.067	4.6	-	-	0.0	35.83
Mar-01	48	37.67	13.89	65	3.03	1.05	25	5.712	1.1	-	-	0.0	16.04
Apr-01	48	31.77	11.71	242	3.33	8.61	223	3.606	6.2	-	-	0.0	26.50
Total	**264**	**42.154**	**85.47**	**599**	**3.74**	**18.6**	**440**	**3.952**	**13.4**	**-**	**-**	**0.0**	**117.4**

The rate of production of shrimps from cast net varied from 1.96 $kg.ha^{-1}$ to 3.03 $kg.ha^{-1}$, in the two seasons.

Hand picking: Similarly, hand picking was carried out during the fag end of the season. The average production of shrimps by hand picking varied from 5.72 $kg.person^{-1}\ h^{-1}$ to 3.26 kg. $person^{-1}\ h^{-1}$ and the rate of production of shrimps by handpicking was 17.0 $kg.ha^{-1}$ to 7.2 $kg.ha^{-1}$ for 1999-2000 to 2000-01 respectively.

Intensity of gear operation

The intensity of sluice net operation increased from 21 in December 1999 to 106 operations in March 2000 and from 25 in December 2000 to 105 in March 2001, indicating maximum intensity of sluice net operations during the month of March. In case of gill net, cast net and handpicking the intensity of operation were also maximum during March during both the seasons in seasonal farms indicating final harvesting using these gears.

5.3.1.2. Perennial farms

The average production from all the gears for perennial farm was 268.2 $kg.ha^{-1}$ during 1999-2000.

Sluice net : Sluice nets were operated throughout the season from November to October every year. The average production of shrimps from sluice net in the perennial field, varied from 10.4 kg. $operation^{-1}$ to 78.9 kg. $operation^{-1}$ during different months. The highest production was recorded during June and its magnitude fluctuated in different months, the lowest being in October. The average production of shrimps in sluice net from perennial farms was 189.2 $kg.ha^{-1}$, during 1999-2000 season.

Gill net: It was observed that gill nets were operated during most of the months with higher intensity during February, April and May coinciding with the final harvesting periods. The average production of shrimps from gill net varied from 0.47 kg.1000 $m^{-2} h^{-1}$ to 3.93 kg.1000 $m^{-2} h^{-1}$ with an average production of 3.38 kg.1000 $m^{-2} h^{-1}$. The highest production was recorded during March. The average production of shrimps in gill net from perennial farms was 39.1 kg.ha^{-1}.

Cast net: Cast nets were also operated for the final harvest along with gill nets. The average production of shrimps from cast net varied from 1.23 kg.$unit^{-1}$ to 4.73 kg.$unit^{-1}$ with an average of 3.6 kg.$unit^{-1}$. The highest production was recorded during June. An average production of 26.7 kg.ha^{-1} was obtained in cast nets during the period of study.

Hand picking: Hand picking was carried out only during the end of the season, July and August. The catch of shrimps by hand picking varied between 1.33 kg.$person^{-1}h^{-1}$ and 1.69 kg.$person^{-1}h^{-1}$. and the rate of production of shrimps varied from 1.5 kg.ha^{-1} to 11.6 kg.ha^{-1} with an average rate of 13.1 kg.ha^{-1}.

Intensity of gear operation

The average intensity of sluice net operation was less during November with 24 operations and an average of 48 operations were carried out during the rest of the period in perennial farms. In the case of gill net, intensity of operations peaked at February, April, May and June. In the case of cast net also the intensity of operations peaked at February, April, May and June indicating periodic intensity of harvesting of these gears. In the case of handpicking the intensity of operation was maximum during August which is the final harvest of shrimps from the perennial farms.

Pillai and Krishnan (1998) recorded an average shrimp production of 353.8 kg.ha^{-1} and 209.5 kg.ha^{-1}, respectively from the seasonal and perennial ponds during 1995-96. George (1974) recorded average annual production of 903.3 kg.ha^{-1} and 838.6 kg.ha^{-1}, respectively from seasonal and perennial farms during the period 1969-72. The average shrimp yield which was as high as 1079 kg.ha^{-1} (Menon, 1954) and 1984

$kg.ha^{-1}$ (Gopinath, 1956) in 1950s gradually declined and reached 353.8 $kg.ha^{-1}$ in 1996 (Pillai and Krishnan, 1998). Average shrimp production recorded by other workers from seasonal farms were 574 $kg.ha^{-1}$ (George *et al*, 1968), 526 $kg.ha^{-1}$ (Gopalan *et al.*, 1982) and 968 $kg.ha^{-1}$ (Purushan , 1989). In experimental culture of *P. indicus* in a seasonal farm, production of 640 to 1458 $kg.ha^{-1}$ (Goplan *et.* al., 1982) and 560 $kg.ha^{-1}$ and (Verghese *et al.*, 1982) has been obtained.

It is estimated that the average annual yield of shrimps and fishes from traditional systems as 1070 to 1570 $kg.ha^{-1}season^{-1}$ while shrimps contribute only 33.3 %, the rest is contributed by fishes such as mullets, pearl spot, tilapia, catfish and crab *Scylla serrata* (Purushan, 1996c) A diminishing trend in shrimp production is noticed during the last two decades from traditional fields.

Raman and Menon (1963) have shown that physical characteristics such as the area of the field, size and number of sluice gates, location, etc. have no influence on the annual yield of prawn from these fields. The higher yield rates in the seasonal field could be attributed to the higher productivity of the fields and its close proximity to the backwaters. The stumps of the paddy help to increase the organic production (Menon, 1954) in the farm and offer better biological environment for the juvenile prawns.

5.3.2. Species composition

The catch composition of shrimp from different harvesting techniques in seasonal and perennial farms is shown in Fig. 5.1.(a) and (b), respectively. The catch composition of different species of shrimps from seasonal and perennial farms is shown in Fig. 5.2.(a) and (b) respectively. The month-wise percentage composition of the four main species of shrimps harvested by different gear in the seasonal and perennial farms is given in Table 5.3. & 5.4., respectively. The shrimp species were *Metapenaeus dobsoni, Penaeus indicus, M. monoceros* and *P. monodon* (Locally called as *Thelly, Choodan, Naran* and *Kara* Chemeen, respectively). Fishes like *Mugil*

Table 5.3. Percentage composition of major species of shrimp landed in different harvesting systems in seasonal farms

Harvesting techniques	SLUICE NET				GILL NET				CAST NET				HAND PICKING				Total species				Harvesting techniques			
Species	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*Sluice net*	*Gill net*	*Cast net*	*Hand picking*
Dec-99	-	2.7	87.6	9.7	-	-	-	-	-	-	-	-	-	-	-	-	-	2.7	87.6	9.7	100.0	-	-	-
Jan-00	-	11.8	82.7	5.4	-	-	-	-	-	-	-	-	-	-	-	-	-	11.8	82.7	5.4	100.0	-	-	-
Feb-00	5.5	56.7	34.6	1.6	-	1.5	0.01	0.02	-	-	-	-	-	-	-	-	5.5	58.2	34.6	1.7	98.5	1.5	-	-
Mar-00	10.0	22.6	48.1	4.9	1.4	3.1	0.03	0.04	0.6	1.1	0.03	0.01	4.9	3.0	0.0	0.1	16.9	29.9	48.2	5.0	85.6	4.6	1.8	8.0
Apr-00	9.1	23.2	38.0	6.0	-	-	-	-	0.5	0.8	0.08	0.08	17.2	4.1	0.4	0.5	26.8	19.6	38.5	6.6	76.3	-	1.4	22.2
Total	**6.4**	**37.0**	**46.3**	**3.6**	**0.5**	**1.7**	**0.01**	**0.03**	**0.2**	**0.4**	**0.01**	**0.03**	**2.5**	**1.2**	**0.03**	**0.04**	**9.6**	**40.0**	**45.9**	**4.5**	**93.3**	**2.2**	**0.7**	**3.8**
Dec-00	-	4.0	86.3	9.7	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	86.3	9.7	100.0	-	-	-
Jan-01	-	10.6	85.2	4.2	-	-	-	-	-	-	-	-	-	-	-	-	-	10.6	85.2	4.2	100.0	-	-	-
Feb-01	6.4	38.8	50.7	1.8	0.7	0.1	0.0	0.03	0.2	0.2	0.04	0.03	0.7	0.2	0.03	0.0	8.0	39.3	50.8	1.9	97.7	0.9	0.5	1.0
Mar-01	10.1	21.1	53.3	3.6	3.7	3.1	0.1	0.01	0.4	0.6	0.03	0.03	2.0	1.9	0.1	0.0	16.1	26.7	53.4	3.7	88.2	6.8	1.1	3.9
Apr-01	10.6	39.0	43.3	7.1	-	-	-	-	-	-	-	-	-	-	-	-	10.6	39.0	13.3	7.1	100.0	-	-	-
Total	**6.7**	**26.4**	**58.1**	**3.3**	**1.7**	**1.2**	**0.04**	**0.02**	**0.2**	**0.3**	**0.04**	**0.02**	**1.0**	**0.8**	**0.03**	**0.03**	**9.7**	**28.7**	**58.2**	**3.3**	**94.5**	**3.0**	**0.6**	**1.9**

Table 5.4. Percentage composition of major species of shrimp landed in different harvesting systems in perennial farms

Harvesting techniques	SLUICE NET				GILL NET				CAST NET				HAND PICKING				Total species				Harvesting techniques			
Species	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*Sluice net*	*Gill net*	*Cast net*	*Hand picking*
Nov-99	0.5	7.4	86.2	5.9	-	-	-	-	-	-	-	-	-	-	-	-	0.5	7.4	86.2	5.9	100.0	-	-	-
Dec-99	-	4.3	90.9	4.8	-	-	-	-	-	-	-	-	-	-	-	-	-	4.3	90.9	4.8	100.0	-	-	-
Jan-00	0.5	6.0	82.0	6.3	0.3	4.4	0.2	0.4	-	-	-	-	-	-	-	-	0.8	10.4	82.1	6.7	94.8	5.2	-	-
Feb-00	1.1	14.5	46.1	0.6	0.6	25.1	0.1	0.1	0.1	11.9	-	-	-	-	-	-	1.8	51.4	46.1	0.6	62.2	25.8	12.0	-
Mar-00	1.6	18.3	66.2	2.3	0.7	4.9	0.1		0.2	5.6	0.1	0.1	-	-	-	-	2.5	28.8	66.3	2.4	88.4	5.7	5.9	-
Apr-00	1.1	9.8	36.3	4.0	0.9	25.4	0.1	0.1	0.3	21.8	-	0.1	-	-	-	-	2.4	57.1	36.5	4.1	51.3	26.5	22.2	-
May-00	1.8	18.9	17.0	1.0	0.6	32.9	0.1	0.1	0.3	27.1	-	0.1	-	-	-	-	2.8	78.9	17.1	1.1	38.6	33.8	27.5	-
Jun-00	0.0	39.4	32.5	4.7	-	12.2	0.2	-	-	10.9	-	-	-	-	-	-	0.0	62.5	32.6	4.7	76.6	12.4	10.9	-
Jul-00	0.1	61.8	24.2	2.0	-	4.1	0.1	-	-	-	0.1	-	0.4	6.5	0.5	0.2	0.6	72.3	24.8	2.2	88.1	4.2	0.1	7.6
Aug-00	0.6	43.4	11.9	2.2	-	-	-	-	-	0.5		0.1	0.7	40.3	0.3	0.1	1.3	84.1	12.2	2.3	58.0	-	0.5	41.4
Sep-00	0.3	23.2	56.6	1.4	0.5	9.5	0.2	0.1	-	7.6	0.4	0.2	-	-	-	-	0.8	40.3	57.1	1.8	81.5	10.3	8.2	-
Oct-00	0.7	12.6	66.7	5.8	1.7	5.8	0.2	0.2	-	5.7	0.3	0.2	-	-	-	-	2.4	24.1	67.3	6.2	85.8	7.9	6.2	-
Total	**0.8**	**23.9**	**43.0**	**2.9**	**0.4**	**13.9**	**0.1**	**0.1**	**0.1**	**9.7**	**0.0**	**0.1**	**0.1**	**4.8**	**0.1**	**0.0**	**1.4**	**52.3**	**43.2**	**3.1**	**70.6**	**14.5**	**9.9**	**5.0**
Nov-00	-	15.7	76.6	5.1	1.0	1.4	0.1	0.2	-	-	-	-	-	-	-	-	1.0	17.1	76.7	5.2	97.4	2.6	-	-
Dec-00	-	7.5	83.1	3.4	2.1	0.8	0.1	0.1	2.7	-	0.1	0.1	-	-	-	-	4.8	8.3	83.3	3.6	94.0	3.1	2.9	-
Jan-01	0.7	12.9	71.2	3.8	0.4	4.2	-	0.1	0.1	6.3	0.1	0.1	-	-	-	-	1.2	23.3	71.3	4.0	88.5	4.8	6.7	-
Feb-01	1.2	3.8	60.4	0.8	3.1	17.8	0.1	-	1.9	10.9	-	-	-	-	-	-	6.2	32.4	60.5	0.8	66.1	21.0	12.8	-
Mar-01	2.4	5.4	75.7	2.8	2.5	4.0	-	-	0.1	6.7	-	0.2	-	-	-	-	5.0	16.1	75.7	3.0	86.3	6.5	7.1	-
Apr-01	1.3	4.0	38.1	0.8	2.0	30.5	-	-	0.2	23.0	-	-	-	-	-	-	3.5	57.5	38.1	0.8	44.1	32.5	23.3	-
Total	**1.1**	**6.6**	**62.8**	**2.1**	**2.1**	**13.6**	**0:1**	**0.1**	**1.0**	**10.3**	**0.1**	**0.1**	**-**	**-**	**-**	**-**	**4.2**	**30.6**	**62.9**	**2.2**	**72.6**	**15.9**	**11.5**	**-**

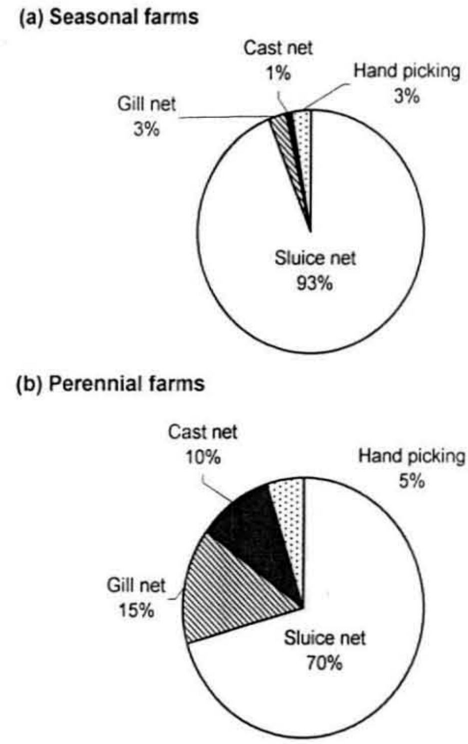


Fig. 5.1. (a, b) Catch composition of total shrimps from different harvesting techniques

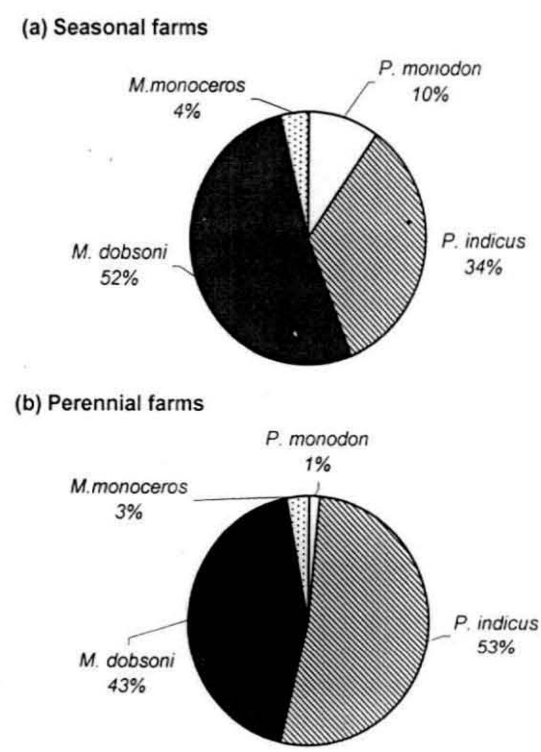


Fig. 5.2. (a, b) Catch composition of different species of shrimps

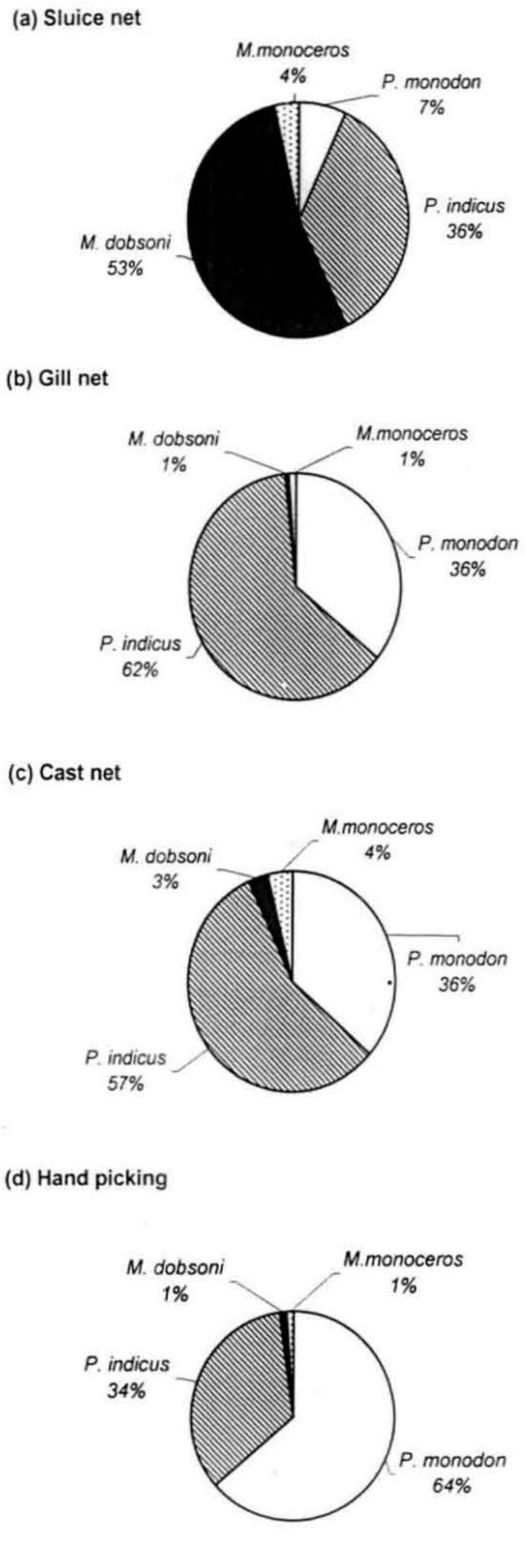


Fig. 5.3. (a to d) Catch composition of shrimps from different gears in seasonal farms

spp., *Chanos* sp., *Etroplus* sp, tilapias, catfishes and a few other species of miscellaneous groups (*Ambasis* sp., *Barbus* sp. *Cyprioides* sp., *Anchoviella sp, Therapon* sp., etc.) and crab (*Scylla serrata*), were also obtained in substantial quantities mainly in the perennial farms.

In seasonal farms, the catch of shrimps dominated in the sluice net (93 %) followed by gillnet and handpicking (3 %) and cast net (1%). In perennial farms the shrimp catch was dominant in the sluice net (70 %). The contribution of shrimps in gill net (15%) and cast net (10 %) and hand picking (5%) was higher when compared to seasonal farms. This was mainly due to comparatively larger size of the perennial farms and shrimp harvesting by filtration alone is not possible and therefore intensity of operation with other gear is more than that of the seasonal farms.

5.3.2.1. Seasonal farms

The percentage catch composition of major species of shrimps from different harvesting techniques *viz.,* sluice net, gill net, cast net and handpicking from seasonal farms are given in Fig. 5.3. (a-d), respectively.The percentage composition in the yield of all species put together show 93.0, 3.0, 1.0 and 3.0 % in the sluice net, gill net, cast net and hand picking, respectively, for both the seasons (December, 1999 to April 2000 and December, 2000 to April, 2001).

The catch composition of major species of shrimps in the seasonal farms shows that *M. dobsoni is* the most dominant contributing 52 % of the total shrimps catch, followed by *P. indicus* (34 %), *P. monodon* (10 %) and *M. monoceros* (4%). This is at variance with the estimates of George (1974) who has given the percentage composition in the yield of different species of prawns as *P. monodon* 0.7 %, *P. indicus* 42.5 %, *M. dobsoni* 53.5 % M. *monoceros* 3.5 % except for *M. dobsoni*. In an earlier study, Pillai and Krishnan, (1998) noted 55.4 % of *P. indicus* in the landings from seasonal farms. The higher percentage of *P. monodon* and *P. indicus* in recent years is mainly due to supplementary stocking of wild seeds in the farms.

Gear-wise catch distribution in seasonal farms

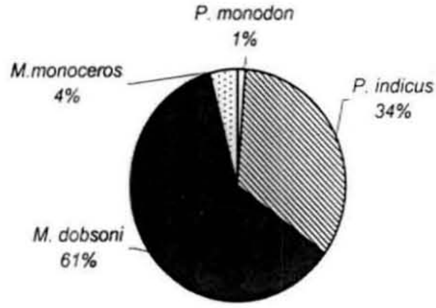
P. monodon: Its contribution ranged from 6.4 % to 10.6 % in sluice net and its average percentage contribution during the two seasons were more or less similar. These were not present in December and January and thereafter its population increased mainly due to stocking. The catch in gill nets ranged from 0.7 to 3.7 %, cast net 0.2 to 0.6 % and hand picking it was 0.7 to 17.2 % of the total shrimp catch.

P. indicus ranked second in order of abundance. In December this species contributed only 2.7 to 4.0 % of the shrimp catch. However, as the season advanced it became more abundant and the peak landings occurred in February when it formed over 56 % in the first season and over 38 % in the second season. It was observed that the percentage contribution of the species in the two seasons in sluice net was 37 and 26.4 %, respectively. However, in case of gill nets, the percentage contribution of this species was more than 3 % in the month of March during both the seasons. In cast nets, the percentage contribution ranged from 0.2 to 1.1 % for both the seasons and by hand picking it was slightly higher and ranged from 0.2 to 4.1 %.

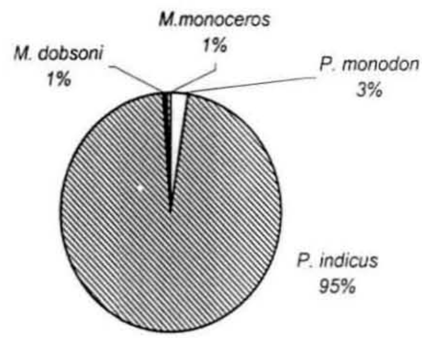
M. dobsoni was the principal species contributing to over 80 % of the catches in case of sluice net from December to January for both the seasons. In last three months of the season, the species formed less than 54 % of the different species of shrimp. It was also observed that the percentage contribution of the species in the two seasons in sluice net was 46.3 and 58.1, % respectively. In the case of other gear the contribution of this species was less than 0.5 %.

M. monoceros: Though this species was obtained throughout the season it formed only a meagre percentage of the total shrimp catch in the sluice net. Its percentage contribution varied between 1.6 and 9.7 % with maximum percentage contribution during December in both the seasons. Average percentage contribution of this species during the two seasons was

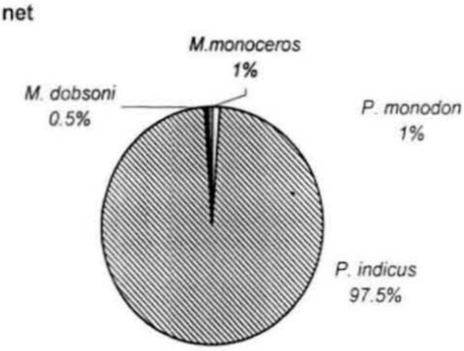
(a) Sluice net



(b) Gill net



(c) Cast net



(d) Hand picking

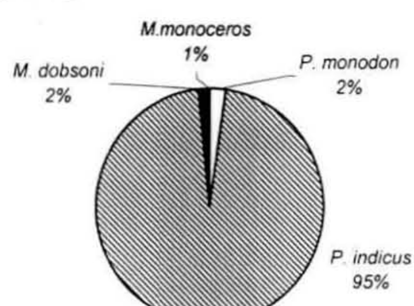


Fig. 5.4. (a to d) Catch composition of shrimps from different gears in perennial farms

more or less similar. The contribution of this species in gill net, cast net and hand picking was less than 0.5 % in each of the fishing methods.

The total percentage composition of different species showed that it was more or less same in both seasons in the case of *P. monodon*. However, percentage composition of *P. indicus* was less during 2000-2001 this could be mainly due to disease problems faced during the year.

5.3.2.2. Perennial farms

The percentage catch composition of major species of shrimps from different harvesting techniques *viz.,* sluice net, gill net, cast net and handpicking from perennial farms are given in Fig. 5.4. (a-d), respectively.The percentage composition in the yield of all species put together show 70.0, 15.0, 10.0 and 5.0 percent in the sluice net, gill net, cast net and hand picking respectively.

The catch composition of major species of shrimps in the perennial farms shows that unlike in the case of seasonal farms *P. indicus* is the most dominant species contributing 53 % of the total shrimps catch, followed by *M. dobsoni* (43.0 %), *M. monoceros* (3.0 %) and *P. monodon* (1.0 %). George (1974) estimated the percentage composition in the yield of different species of prawns as *P. monodon* (0.7 %), *M. monoceros* (4.0 %) *P. indicus* 34.5 %, *M. dobsoni 60.4* %. In the earlier study Pillai and Krishnan, (1998) noted 65.1 % of *P. indicus* which is more or less similar to the results obtained during the study indicating supplementary stocking of wild and hatchery seeds in the farms.

The percentage composition of shrimps in the sluice gate was much less compared to the seasonal farms. This was mainly due to comparatively larger size of the perennial farms and shrimp harvesting by filtration alone is not possible and therefore intensity of operation with other gear is more than that of the seasonal farms.

Gear-wise catch distribution in perennial farms

P. monodon: Contribution of this species in sluice net varied from 0.5 % to 1.8 % and its average contribution was 0.8%. The percentage catch of *P. monodon* was less when compared to seasonal farms. This could be due to stocking of this species in the seasonal farms. The catch in gill nets ranged from 0.3 to 1.7 %, cast net 0.1 to 0.3 % and hand picking it was 0.4 to 0.7 % of the total shrimp catch.

P. indicus ranked second in order of abundance as in the case of seasonal farms. Maximum contribution is seen during June to August ranging from 39.4 % to 61.8 % and least contribution was during November to January, 0.4 to 7.4 % in sluice net. However, as the season advanced it was more abundant. It was observed that the average percentage contribution of the species in sluice net was 23.9. The contribution of *P. indicus* from gill nets, cast and handpicking was quite substantial forming 13.9 %, 9.7 % and 4.8 %, respectively.

M. dobsoni was the principal species as in the case of perennial farms contributing to over 80 % of the catch in case of sluice net from November 1999 to January 2000. It was also observed that the average percentage contribution of the species was 43. In the case of other gear the contribution of this species was less than 0.1 % which is similar to the catch trends in the seasonal farms.

M. monoceros: This species formed only a meagre percentage of the total shrimp catches in the sluice net . The contribution of this species varied from 0.6 to 6.3 % with maximum percentage contribution during January. Average percentage contribution of this species was 2.9. The percentage of this species in gill net, cast and hand picking was very less, contributing to 0.1 or less in the total shrimp catch of different gears.

Table 5.5. Month-wise size and sex ratio of different species of shrimps harvested in sluice nets in the seasonal farms

	P. monodon		Sex ratio		*P. indicus*		Sex ratio		*M. dobsoni*		Sex ratio		*M. monoceros*		Sex ratio	
Month & Year	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F
Dec-99	-	-	-	-	65-112	82.6	48.0	52.0	30-66	36.2	44.4	55.6	-	-	-	-
Jan-00	-	-	-	-	80-153	119.5	43.4	56.6	40-85	55.9	44.5	55.5	50-110	85.6	47.5	52.5
Feb-00	155-195	177.8	40.0	60.0	95-151	122.8	41.4	58.6	35-185	54.3	48.3	51.7	60-105	84.5	53.3	46.7
Mar-00	164-195	180.2	36.4	63.6	110-138	122.4	42.0	58.0	46-68	55.4	50.3	49.7	76-99	86.3	50.0	50.0
Apr-00	124-200	174.0	53.0	47.0	95-58	117.8	40.0	60.0	50-68	57.3	44.7	55.3	70-94	82.0	48.7	51.3
Dec-00	-	-	-	-	58-152	84.1	52.0	48.0	23-68	40.4	51.3	48.7	61-94	79.7	56.0	44.0
Jan-01	-	-	-	-	79-152	117.1	45.8	54.2	41-90	56.6	42.3	57.7	50-105	84.5	47.0	53.0
Feb-01	160-195	177.7	49.0	51.0	94-154	122.7	35.9	64.1	30-88	54.6	52.3	47.7	60-108	84.0	51.0	49.0
Mar-01	170-20	181.0	45.3	54.7	110-148	123.6	50.2	49.8	36-70	55.4	49.7	50.3	65-99	85.7	51.7	48.3
Apr-01	120-204	173.3	44.0	56.0	90-140	117.3	44.0	56.0	46-69	57.5	47.3	52.7	72-96	82.2	50.4	49.6

Table 5.6. Month-wise size and sex ratio of different species of shrimps harvested in gill nets in the seasonal farms

Month & Year	*P. monodon*		Sex ratio		*P. indicus*		Sex ratio		*M. dobsoni*		Sex ratio		*M. monoceros*		Sex ratio	
	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F
Feb-00	-	-	-	-	105-160	121.3	52.0	48.0	70-90	78.0	48.3	51.7	60-105	84.5	53.3	46.0
Mar-00	147-202	167.4	46.6	53.4	65-152	114.1	51.7	48.3	60-100	80.1	50.3	49.7	76-99	86.3	50.0	50.0
Feb-01	168-202	185.3	42.0	58.0	95-125	115.7	55.3	44.7	72-95	68.5	52.3	47.7	60-108	84.0	51.0	49.0
Mar-01	145-200	175.9	41.2	58.8	99-130	122.1	57.3	42.7	75-101	66.3	49.7	50.3	65-99	85.7	51.7	48.3

Table 5.7. Month-wise size and sex ratio of different species of shrimps harvestted in cast nets in the seasonal farms

	P. monodon		Sex ratio		*P. indicus*		Sex ratio		*M. dobsoni*		Sex ratio		*M.monoceros*		Sex ratio	
Month & Year	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F
Mar-00	142-190	169.2	52.6	47.4	60-145	106.3	45.2	54.8	45-69	53.2	50.0	50.0	76-99	84.3	50.0	50.0
Apr-00	145-182	171.2	52.0	48.0	70-132	100.9	44.0	56.0	53-68	58.0	44.2	55.8	70-94	83.0	48.0	52.0
Feb-01	149-182	174.9	44.0	56.0	92-125	103.9	36.0	64.0	32-87	55.2	50.3	49.7	60-108	84.1	51.0	49.0
Mar-01	145-208	181.5	56.8	43.2	92-130	112.6	52.6	47.4	36-75	55.6	49.2	50.8	65-99	85.8	51.0	49.0

Table 5.8. Month-wise size and sex ratio of different species of shrimps harvested by hand picking in the seasonal farm

Month & Year	*P. monodon*		Sex ratio		*P. indicus*		Sex ratio		*M. dobsoni*		Sex ratio		*M. monoceros*		Sex ratio	
	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F
Mar-00	130-214	182.6	53.0	47.0	90-140	100.5	51.5	48.5	40-60	58.0	45.0	65.0	75-90	70.5	41.0	59.0
Apr-00	137-212	184.7	55.0	45.0	91-142	106.9	50.5	49.5	51-68	60.2	60.2	55.1	80-100	92.1	48.0	52.0
Feb-01	143-202	188.0	44.0	56.0	91-132	92.5	50.4	49.6	35-88	65.8	65.8	50.0	82-102	99.2	45.0	55.0
Mar-01	143-202	191.4	52.5	47.5	90-140	106.2	46.1	53.9	45-70	66.2	66.2	52.0	88-100	85.6	48.1	51.9

Table 5.9. Month-wise size and sex ratio of different species of shrimps harvested in sluice nets in the perennial farms

Month & Year	*P. monodon* Length (mm)	*P. monodon* Average length (mm)	Sex ratio M	Sex ratio F	*P. indicus* Length (mm)	*P. indicus* Average length (mm)	Sex ratio M	Sex ratio F	*M. dobsoni* Length (mm)	*M. dobsoni* Average length (mm)	Sex ratio M	Sex ratio F	*M. monoceros* Length (mm)	*M. monoceros* Average length (mm)	Sex ratio M	Sex ratio F
Nov-99	168-200	179.1	48.0	52.0	100-210	123.6	42.0	58.0	50-86	65.8	46.7	53.3	52-98	78.0	53.6	46.4
Dec-99	-				65-157	114.4	43.0	57.0	30-92	53.5	47.8	52.2	60-89	78.6	49.5	50.5
Jan-00	165-227	189.6	46.8	53.2	75-154	123.8	41.6	58.4	35-95	57.0	48.0	52.0	50-115	82.0	47.4	52.6
Feb-00	148-202	176.7	58.8	41.2	65-185	125.3	49.2	50.8	35-110	59.3	52.8	47.2	58-130	82.1	49.1	50.9
Mar-00	150-210	179.1	41.5	58.5	68-155	121.4	44.6	55.4	28-110	58.3	43.9	56.1	55-102	84.2	53.5	46.5
Apr-00	124-210	180.4	48.0	52.0	81-175	118.7	49.8	50.2	40-86	60.4	44.4	55.6	60-110	81.6	47.2	52.8
May-00	175-206	187.0	38.8	61.2	70-154	114.5	49.6	50.4	30-95	60.5	50.5	49.5	42-106	85.5	48.3	51.7
Jun-00	185-240	230.0	14.3	85.7	78-185	118.6	41.6	58.4	25-102	66.9	35.4	64.6	60-125	87.8	38.7	61.3
Jul-00	195-210	199.8	48.0	52.0	60-155	104.3	39.4	60.6	28-98	68.4	40.6	59.4	75-128	98.6	53.8	46.2
Aug-00	156-211	188.2	51.0	49.0	65-140	105.3	44.2	55.8	28-10	69.4	46.2	53.8	69-120	100.2	49.3	50.7
Sep-00	120-150	127.2	56.0	44.0	62-142	101.3	45.3	54.7	32-101	68.9	44.6	55.4	80-126	100.3	48.0	52.0
Oct-00	115-162	124.4	44.0	56.0	75-142	103.1	41.9	58.1	30-102	67.7	46.2	53.8	67-98	84.5	42.0	58.0
Nov-00	-	-	-	-	65-130	113.2	35.1	64.9	45-88	61.8	55.5	44.5	50-95	76.8	53.0	47.0
Dec-00	-	-	-	-	58-150	101.1	52.6	47.4	23-86	51.4	44.3	55.7	51-98	77.7	47.4	52.6
Jan-01	160-210	188.9	35.8	64.2	75-158	121.9	45.3	54.7	35-90	56.8	47.6	52.4	50-115	78.1	47.4	52.6
Feb-01	130-204	176.9	48.8	51.2	68-154	123.7	43.2	56.8	30-90	57.3	53.3	46.8	54-117	82.9	49.9	50.1
Mar-01	140-212	181.5	48.1	51.9	72-210	122.0	45.4	54.6	29-86	60.4	46.1	53.9	42-99	84.8	52.3	47.7
Apr-01	120-210	189.8	50.0	50.0	65-148	116.0	43.3	56.7	42-85	58.8	49.7	50.3	60-96	76.5	45.2	54.8

Table 5.10. Month-wise size and sex ratio of different species of shrimps harvested in gill nets in the perennial farms

Month & Year	*P. monodon* Length (mm)	*P. monodon* Average length (mm)	Sex ratio M	Sex ratio F	*P. indicus* Length (mm)	*P. indicus* Average length (mm)	Sex ratio M	Sex ratio F	*M. dobsoni* Length (mm)	*M. dobsoni* Average length (mm)	Sex ratio M	Sex ratio F	*M. monoceros* Length (mm)	*M. monoceros* Average length (mm)	Sex ratio M	Sex ratio F
Jan-00	160-226	189.2	46.9	53.1	120-166	146.0	44.3	55.7	99-115	95.0	48.0	52.0	50-115	82.0	46.0	54.0
Feb-00	130-210	174.3	35.2	64.8	85-190	135.0	39.5	60.5	98-112	98.0	52.8	47.2	58-130	82.1	49.0	51.0
Mar-00	170-218	183.5	50.0	50.0	99-152	134.1	39.8	60.2	90-115	90.1	43.9	56.1	55-102	84.2	53.2	46.8
Apr-00	160-210	179.9	44.9	55.1	80-190	130.3	39.3	60.7	100-112	75.3	44.0	56.0	80-110	82.2	47.0	53.0
May-00	162-212	189.9	44.6	55.4	85-210	129.0	45.3	54.7	101-116	78.2	50.4	49.6	42-106	86.4	48.2	51.8
Jun-00	178-202	182.2	36.0	64.0	89-252	116.0	32.4	67.6	105-114	90.6	35.5	64.5	60-125	88.2	38.2	61.8
Jul-00	-	-	-	-	100-146	129.3	48.3	51.7	90-119	92.1	40.0	60.0	75-128	99.0	53.6	46.4
Aug-00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sep-00	162-200	176.4	45.0	55.0	96-155	127.1	42.2	57.8	62-101	70.5	44.6	55.4	80-126	101.0	48.0	52.0
Oct-00	178-202	193.6	52.0	48.0	92-150	123.3	38.6	61.4	98-112	69.2	46.0	54.0	67-98	85.2	42.0	58.0
Nov-00	162-208	187.5	45.5	54.5	110-128	119.1	40.0	60.0	101-116	60.6	55.0	45.0	50-95	79.2	50.0	50.0
Dec-00	162-220	182.7	56.0	44.0	-		-	-	90-110	51.4	44.2	55.8	51-98	78.0	47.4	52.6
Jan-01	140-202	169.2	44.8	55.2	90-153	126.7	36.2	63.8	90-119	56.8	47.2	52.8	50-115	79.2	47.0	53.0
Feb-01	160-205	182.0	47.3	52.7	85-190	128.3	43.5	56.5	60-75	58.2	50.0	40.0	54-117	85.0	49.0	51.0
Mar-01	165-205	181.2	44.2	55.8	100-185	130.8	38.2	61.8	68-90	55.6	46.1	53.9	50-98	85.6	52.4	47.6
Apr-01	160-210	187.2	45.0	55.0	80-190	130.2	43.1	56.9	70-85	54.2	49.3	50.7	60-100	77.3	45.6	54.4

Table 5.11. Month-wise size and sex ratio of different species of shrimps harvested in cast nets in the perennial farms

	P. monodon		Sex ratio		*P. indicus*		Sex ratio		*M. dobsoni*		Sex ratio		*M. monoceros*		Sex ratio	
Month & Year	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F	Length (mm)	Average length (mm)	M	F
Nov-99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dec-99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jan-00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Feb-00	120-215	163.6	28.6	71.4	66-175	134.3	37.4	62.6	50-110	60.0	52.0	48.0	60-130	83.2	49.0	51.0
Mar-00	195-202	198.7	36.1	63.9	65-150	119.1	47.0	53.0	50-111	61.2	44.1	58.9	62-133	85.0	55.0	45.0
Apr-00	120-230	172.9	42.4	57.6	62-175	124.7	41.3	58.7	52-90	62.4	45.0	55.0	65-110	88.0	58.0	42.0
May-00	121-205	181.6	38.4	61.6	65-175	137.9	45.8	54.2	53-95	63.5	50.0	50.0	48-106	90.0	48.2	51.8
Jun-00	120-215	193.1	22.2	77.8	60-170	107.9	28.5	71.5	58-102	67.0	36.0	64.0	65-118	92.0	39.6	61.4
Jul-00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aug-00	120-205	175.0	0.0	100.0	100-170	143.5	42.0	58.0	45-110	70.5	50.0	50.0	70-120	112.0	49.0	51.0
Sep-00					100-165	137.7	40.3	59.7	55-101	80.6	45.0	55.0	85-126	115.0	49.0	51.0
Oct-00	160-210	190.0	0.0	100.0	66-165	131.5	43.6	56.4	60-110	88.0	46.3	53.7	68-99	89.0	42.0	58.0
Nov-00		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dec-00	152-220	197.2	42.0	58.0	-	-			45-88	60.4	44.1	55.9	52-98	87.0	47.0	53.0
Jan-01	120-220	191.7	44.0	56.0	100-175	127.4	47.0	53.0	49-90	58.0	49.0	51.0	55-119	88.0	47.0	53.0
Feb-01	150-215	188.7	41.5	58.5	68-175	132.4	39.9	60.1	53-96	62.3	49.0	51.0	60-117	84.2	49.8	51.2
Mar-01					68-150	121.8	61.5	38.5	40-86	65.4	47.0	53.0	50-99	85.3	40.0	50.0
Apr-01	130-225	177.9	40.5	59.5	60-175	122.1	47.3	52.7	48-85	70.0	49.7	50.3	65-98	86.3	45.1	54.9

Table 5.12. Month-wise size and sex ratio of different species of shrimps harvested by hand picking in perennial farms

Month & Year	*P. monodon* Length (mm)	Average length (mm)	Sex ratio M	F	*P. indicus* Length (mm)	Average length (mm)	Sex ratio M	F	*M. dobsoni* Length (mm)	Average length (mm)	Sex ratio M	F	*M. monoceros* Length (mm)	Average length (mm)	Sex ratio M	F
Jul-00	168-200	178.6	51.5	48.5	48-140	107.9	53.3	46.7	50-98	70.2	40.0	60.0	74-118	100.5	48.0	52.0
Aug-00	162-212	184.5	53.2	46.8	52-150	109.2	43.2	56.8	55-98	75.1	46.5	63.5	75-122	112.0	49.1	50.9

Table 5.13. Average length of major species of shrimp landed in different harvesting systems in seasonal farms

Harvesting techniques	SLUICE NET				GILL NET				CAST NET				HAND PICKING				Total species			
Species	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*
Dec-99	-	82.6	36.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82.6	36.2	-
Jan-00	-	119.5	55.9	85.6	-	-	-	-	-	-	-	-	-	-	-	-	-	119.5	55.9	85.6
Feb-00	177.8	122.8	54.3	84.5	-	121.3	78.0	84.5	-	-	-	-	-	-	-	-	177.8	122.5	54.3	84.5
Mar-00	180.2	122.4	55.4	86.3	167.4	114.1	80.1	86.3	169.2	100.3	58.2	84.3	182.6	100.5	58.0	70.5	178.0	108.0	55.4	86.3
Apr-00	174.0	117.8	57.3	82.0	-	-	-	-	171.2	100.9	58.0	83.0	184.7	106.9	60.2	92.1	182.0	108.0	57.3	82.0
Average	**177.3**	**113.0**	**51.8**	**84.6**	**167.4**	**117.7**	**79.1**	**85.4**	**170.2**	**100.6**	**55.6**	**83.7**	**183.7**	**103.7**	**59.1**	**81.3**	**179.3**	**108.1**	**51.8**	**84.6**
Dec-00	-	84.1	40.4	79.7	-	-	-	-	-	-	-	-	-	-	-	-	-	84.1	40.4	79.6
Jan-01	-	117.1	56.6	84.5	-	-	-	-	-	-	-	-	-	-	-	-	-	117.1	56.6	84.5
Feb-01	177.7	122.7	54.6	84.0	185.3	115.7	68.5	84.0	174.9	103.9	55.2	84.1	188.0	92.5	65.8	99.2	186.0	111.0	54.6	84.0
Mar-01	181.0	123.6	55.4	85.7	175.9	122.1	66.3	85.7	181.5	112.6	55.6	85.8	191.4	106.2	66.2	85.6	187.0	109.0	55.4	85.7
Apr-01	173.3	117.3	57.5	82.2	-	-	-	-	-	-	-	-	-	-	-	-	173.0	117.3	57.4	82.2
Average	**177.3**	**113.0**	**52.9**	**83.2**	**180.6**	**118.9**	**67.4**	**84.9**	**178.2**	**108.3**	**55.4**	**85.0**	**189.7**	**99.4**	**66.0**	**92.4**	**182.0**	**107.7**	**52.9**	**83.2**

Table 5.14. Average length of major species of shrimp landed in different harvesting systems in perennial farms

Harvesting techniques	SLUICE NET				GILL NET				CAST NET				HAND PICKING				Total species			
Species	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P.monodon*	*P. indicus*	*M. dobsoni*	*M. monoceros*
Nov-99	179.1	123.6	65.8	78.0	-	-	-	-	-	-	-	-	-	-	-	-	179.1	123.6	65.7	78.0
Dec-99	-	114.4	53.5	78.6	-	-	-	-	-	-	-	-	-	-	-	-	-	124.9	67.9	78.6
Jan-00	189.6	123.8	57.0	82.0	189.2	146.0	95.0	82.0	-	-	-	-	-	-	-	-	189.3	141.1	58.1	78.3
Feb-00	176.7	125.3	59.3	82.1	174.3	135.0	98.0	82.1	163.6	134.3	60.0	83.2	-	-	-	-	171.4	134.4	64.3	78.8
Mar-00	179.1	121.4	58.3	84.2	183.5	134.1	90.1	84.2	198.7	119.1	61.2	85.0	-	-	-	-	181.3	126.0	61.3	81.6
Apr-00	180.4	118.7	60.4	81.6	179.9	130.3	75.3	82.2	172.9	124.7	62.4	88.0	-	-	-	-	177.5	126.7	62.0	81.4
May-00	187.0	114.5	60.5	85.5	189.9	129.0	78.2	86.4	181.6	137.9	63.5	90.0	-	-	-	-	181.1	130.6	60.5	85.5
Jun-00	230.0	118.6	66.9	87.8	182.2	116.0	90.6	88.2	193.1	107.9	67.0	92.0	-	-	-	-	197.1	113.5	66.9	87.8
Jul-00	199.8	104.3	68.4	98.6	-	129.3	92.1	99.0	-	-	-	-	178.6	107.9	70.2	100.5	199.8	117.7	68.4	98.6
Aug-00	188.2	105.3	69.4	100.2	-	-	-	-	175.0	143.5	70.5	112.0	184.5	109.2	75.1	112.0	185.9	109.0	69.4	100.2
Sep-00	127.2	101.3	68.9	100.3	176.4	127.1	70.5	101.0		137.7	80.6	115.0	-	-	-	-	166.6	120.5	68.9	100.3
Oct-00	124.4	103.1	67.7	84.5	193.6	123.3	69.2	85.2	190.0	131.5	88.0	89.0	-	-	-	-	161.2	122.2	67.7	84.5
Average	**178.3**	**114.5**	**63.0**	**87.0**	**183.6**	**130.0**	**84.3**	**87.8**	**182.1**	**129.6**	**69.2**	**94.3**	**181.6**	**108.6**	**72.7**	**106.3**	**180.9**	**124.2**	**65.1**	**86.1**
Nov-00		113.2	61.8	76.8	187.5	119.1	60.6	79.2	-	-	-	-	-	-	-	-	187.5	113.8	61.8	76.8
Dec-00	-	101.1	51.4	77.7	182.7	-	51.4	78.0	197.2	-	60.4	87.0	-	-	-	-	192.3	107.5	59.1	77.4
Jan-01	188.9	121.9	56.8	78.1	169.2	126.7	56.8	79.2	191.7	127.4	58.0	88.0	-	-	-	-	180.1	126.5	56.9	72.7
Feb-01	176.9	123.7	57.3	82.9	182.0	128.3	58.2	85.0	188.7	132.4	52.3	84.2	-	-	-	-	180.8	132.6	59.4	82.0
Mar-01	181.5	122.0	60.4	84.8	181.2	130.8	55.6	85.6	-	121.8	65.4	85.3	-	-	-	-	191.5	125.0	64.1	84.1
Apr-01	189.8	116.0	58.8	76.5	187.2	130.2	54.2	77.3	177.9	122.1	70.0	86.3	-	-	-	-	183.6	124.7	59.5	73.7
Average	**184.3**	**116.3**	**57.8**	**79.5**	**181.6**	**127.0**	**56.1**	**80.7**	**188.9**	**125.9**	**61.2**	**86.2**	-	-	-	-	**186.0**	**121.7**	**60.1**	**77.8**

Table 5.15. Size range and modal length of major species of shrimps from different harvesting techinques in seasonal farms

Harvesting techniques	*P. modonon*		*P. indicus*		*M. dobsoni*		*M. monoceros*	
	Size range (mm)	Modal length (mm)	Size range (mm)	Modal length (mm)	Size range (mm)	Modal length (mm)	Size range (mm)	Modal length (mm)
Sluice net	155-204	162.0	55-155	120.0	30-90	52.0	50-108	85.0
Gill net	147-202	184.0	95-160	130.0	70-101	80.0	60-108	84.0
Cast net	142-208	182.0	60-145	112.0	32-87	68.0	60-108	81.0
Hand picking	130-214	196.0	90-142	95.0	35-88	70.0	75-102	78.0

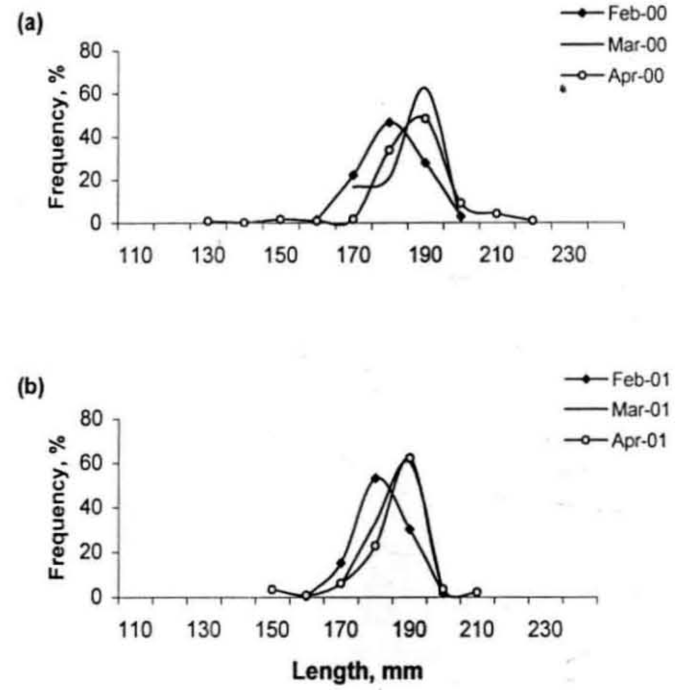


Fig. 5.5. (a,b) Length frequency of *P. monodon* in sluice net from seasonal farms

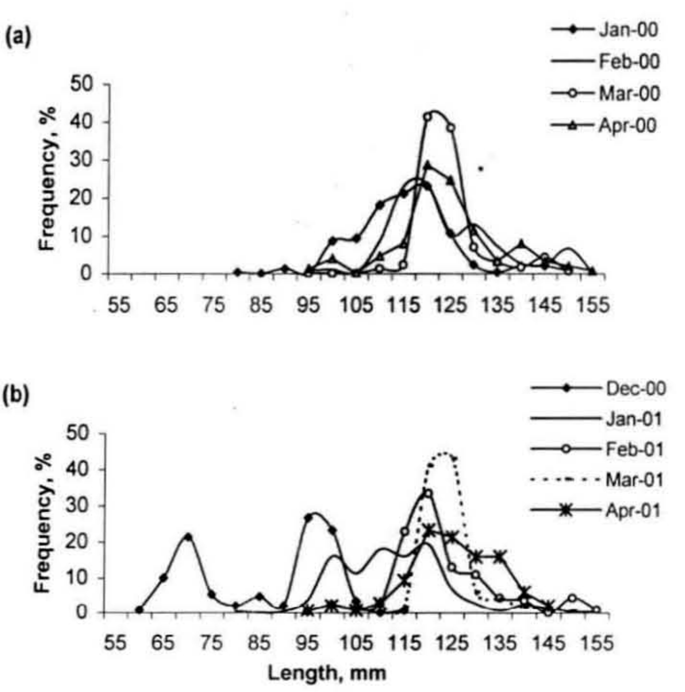


Fig. 5.6. (a,b) Length frequency of *P. indicus* in sluice net from seasonal farms

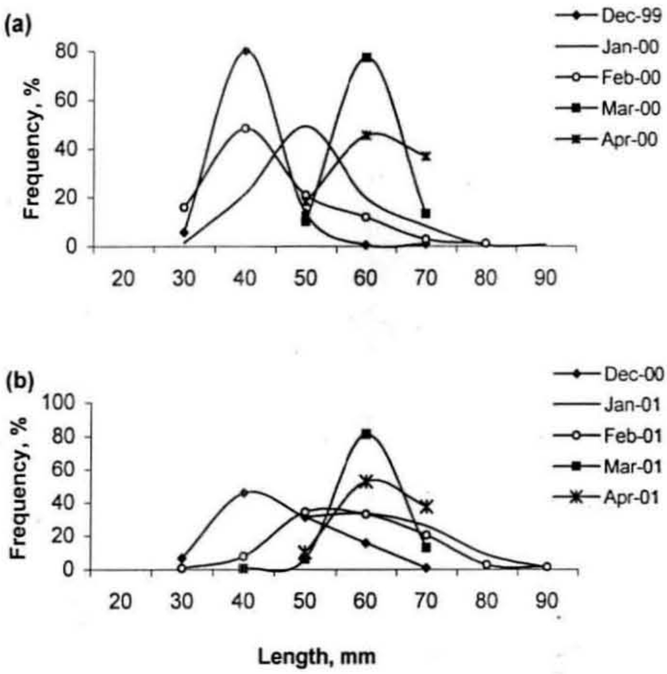


Fig. 5.7. (a,b) Length frequency of *M. dobsoni* in sluice net from seasonal farms

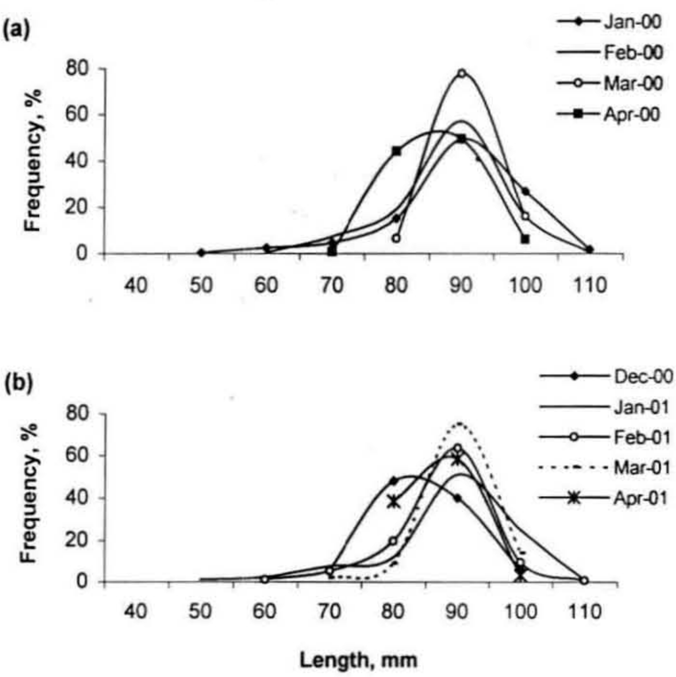


Fig. 5.8. (a,b) Length frequency of *M. monoceros* in sluice net from seasonal farms

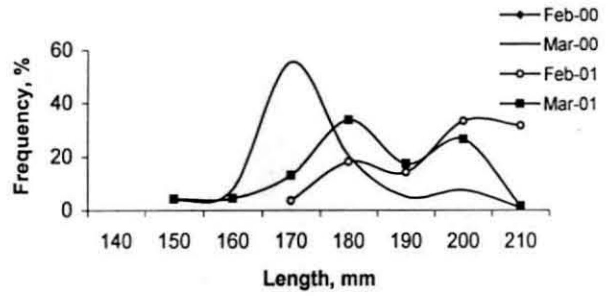


Fig. 5.9. Length frequency of *P. monodon* in gill net from seasonal farms

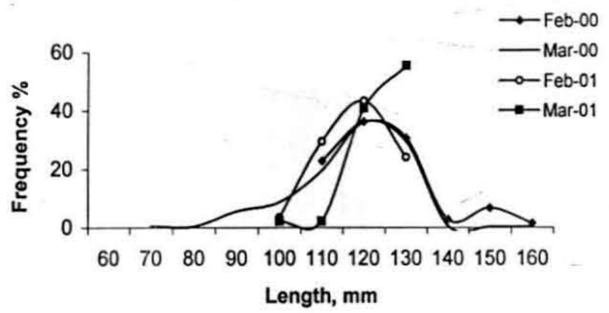


Fig. 5.10. Length frequency of *P. indicus* in gill net from seasonal farms

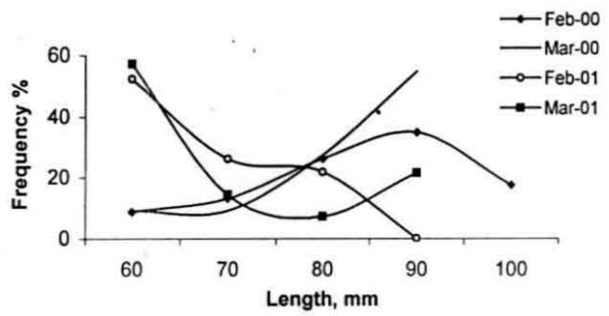


Fig. 5.11. Length frequency of *M. dobsoni* in gill net from seasonal farms

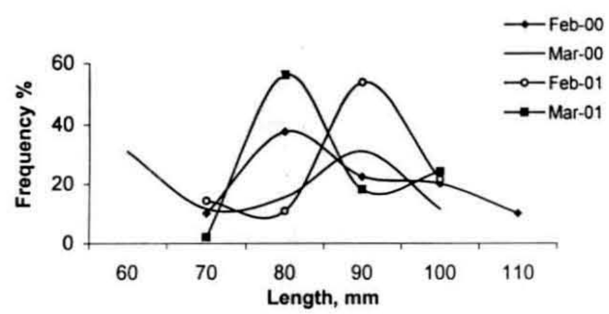


Fig. 5.12. Length frequency of *M. monoceros* in gill net from seasonal farms

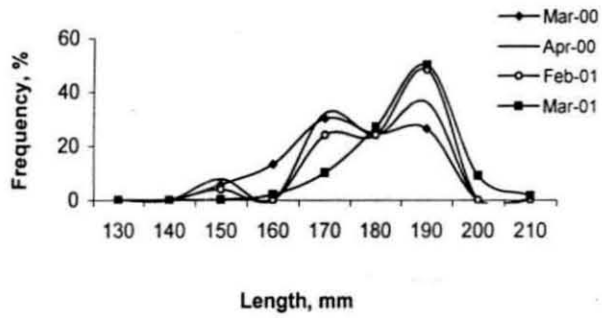


Fig. 5.13. Length frequency of *P. monodon* in cast net from seasonal farms

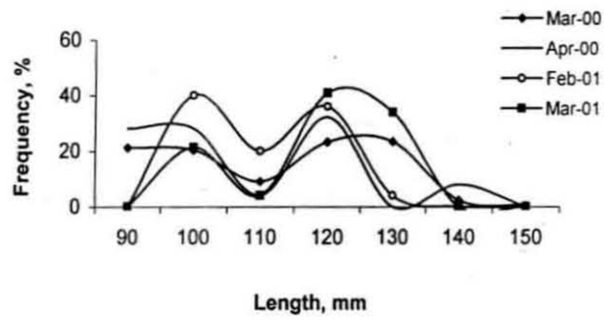


Fig. 5.14. Length frequency of *P. indicus* in cast net from seasonal farms

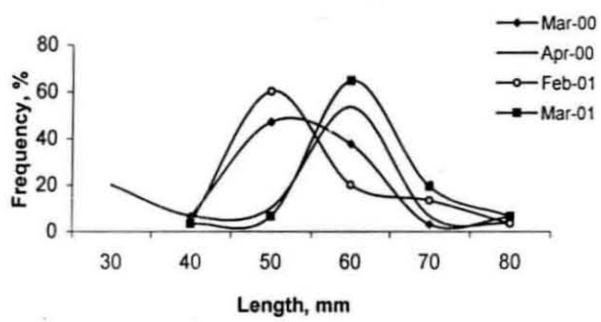


Fig. 5.15. Length frequency of *M. dobsoni* in cast net from seasonal farms

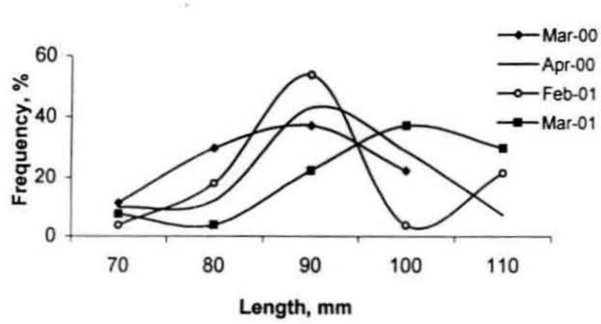


Fig. 5.16. Length frequency of *M. monoceros* in cast net from seasonal farms

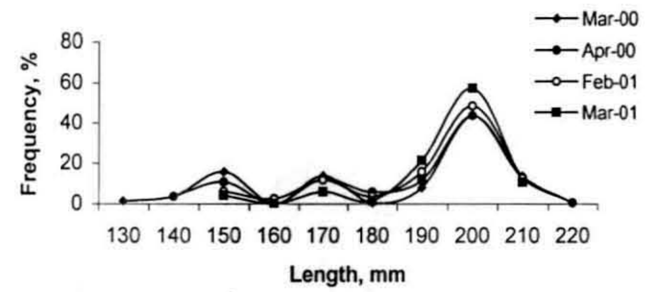


Fig. 5.17. Length frequency of *P. monodon* in hand picking from seasonal farm

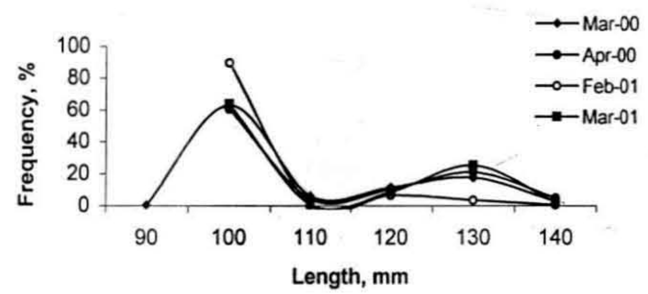


Fig. 5.18. Length frequency of *P. indicus* in hand picking from seasonal farm

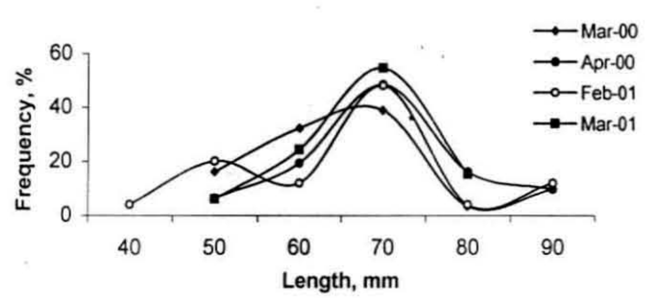


Fig. 5.19. Length frequency of *M. dobsoni* in hand pikcing from seasonal farm

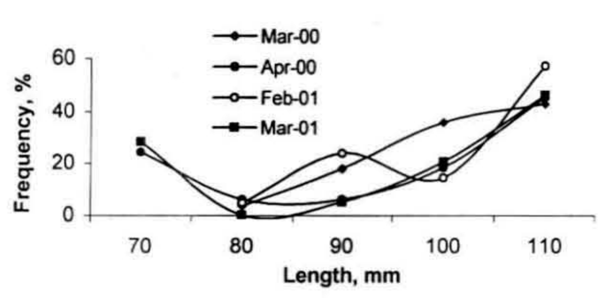


Fig. 5.20. Length frequency of *M. monoceros* in hand picking from seasonal farm

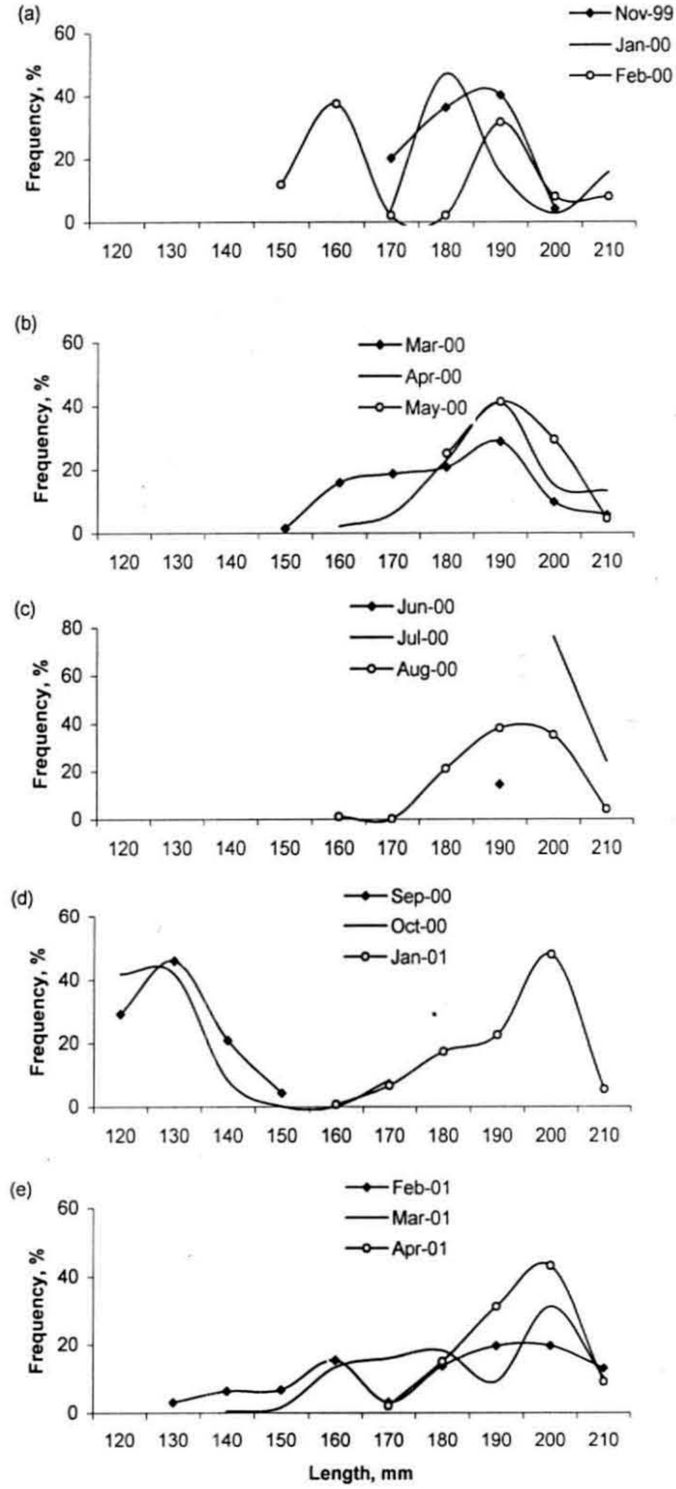


Fig. 5.21. (a to e) Length frequency of *P. monodon* in sluice net from perennial farms

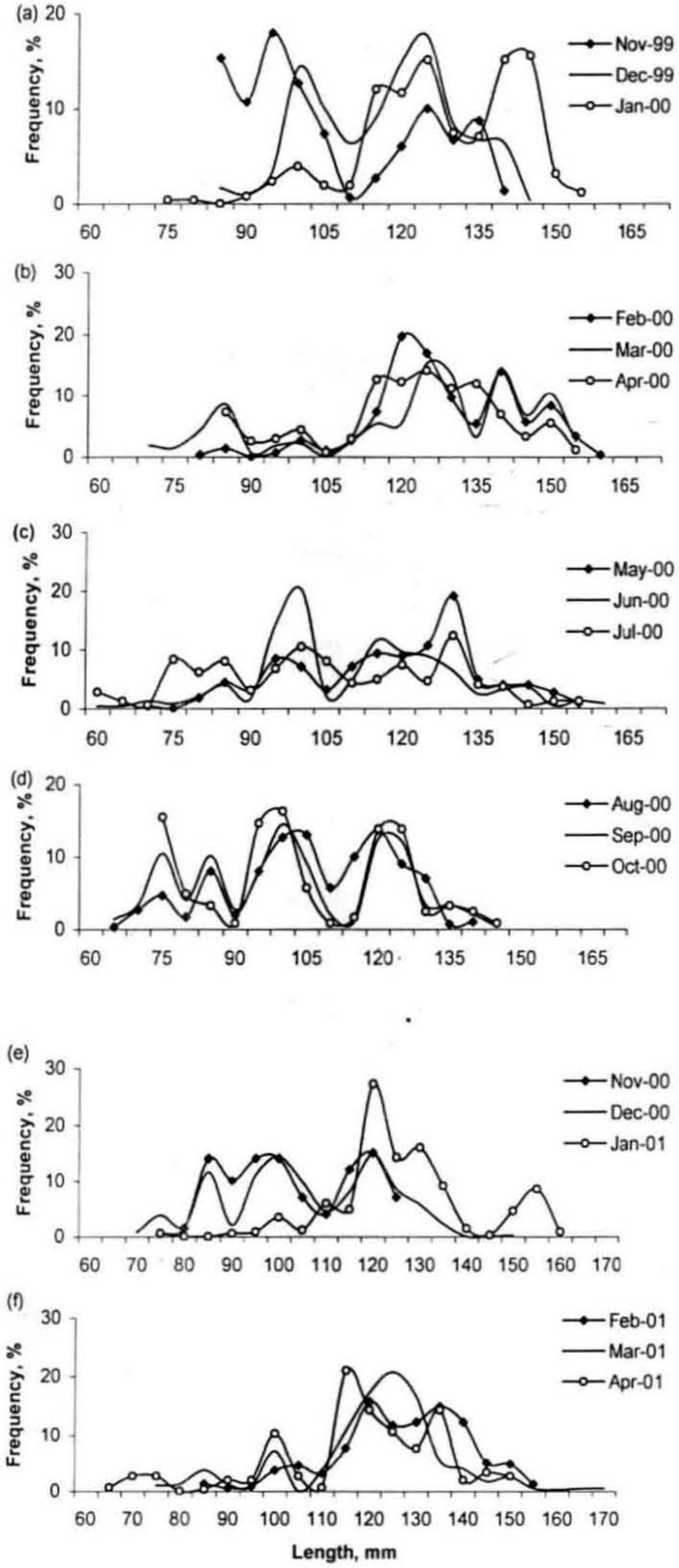


Fig. 5.22. (a to f) Length frequency of *P. indicus* in sluice net from perennial farms

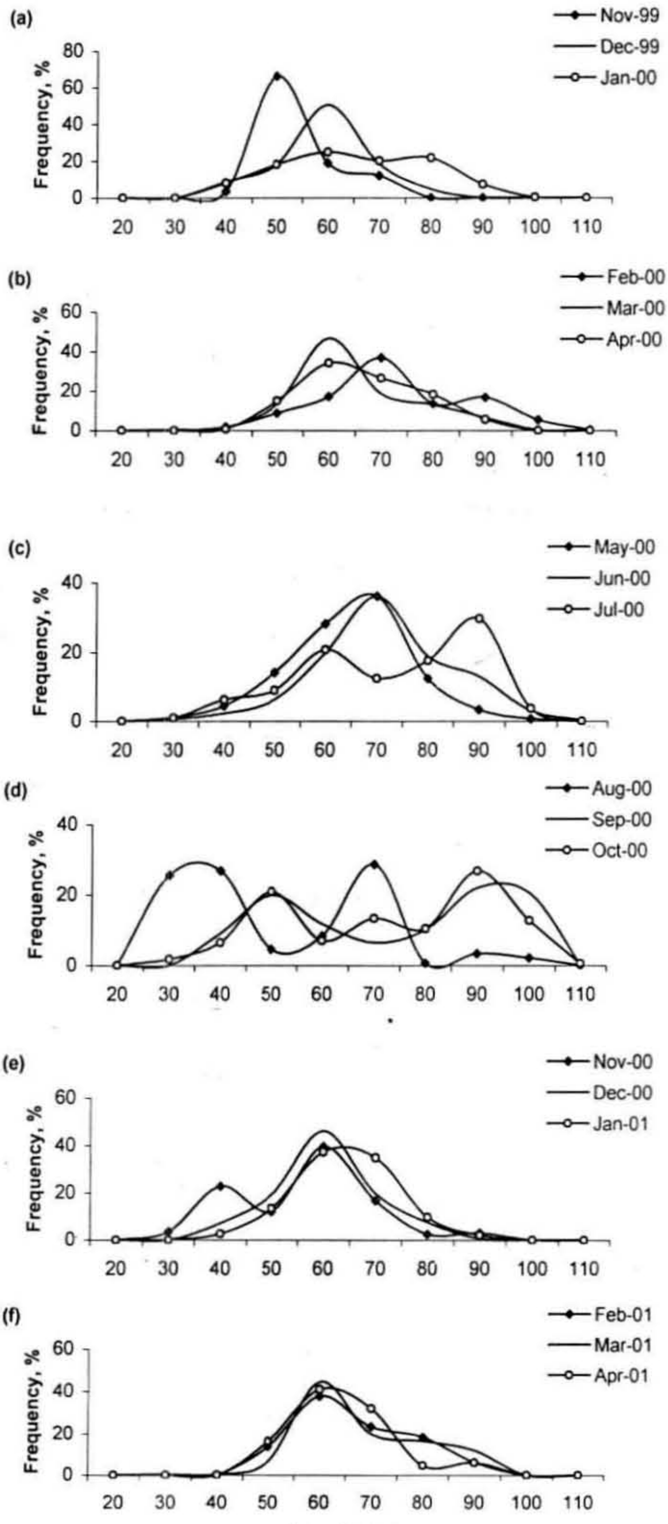


Fig. 5.23. (a to f) Length frequency of *M. dobsoni* in sluice net from perennial farms

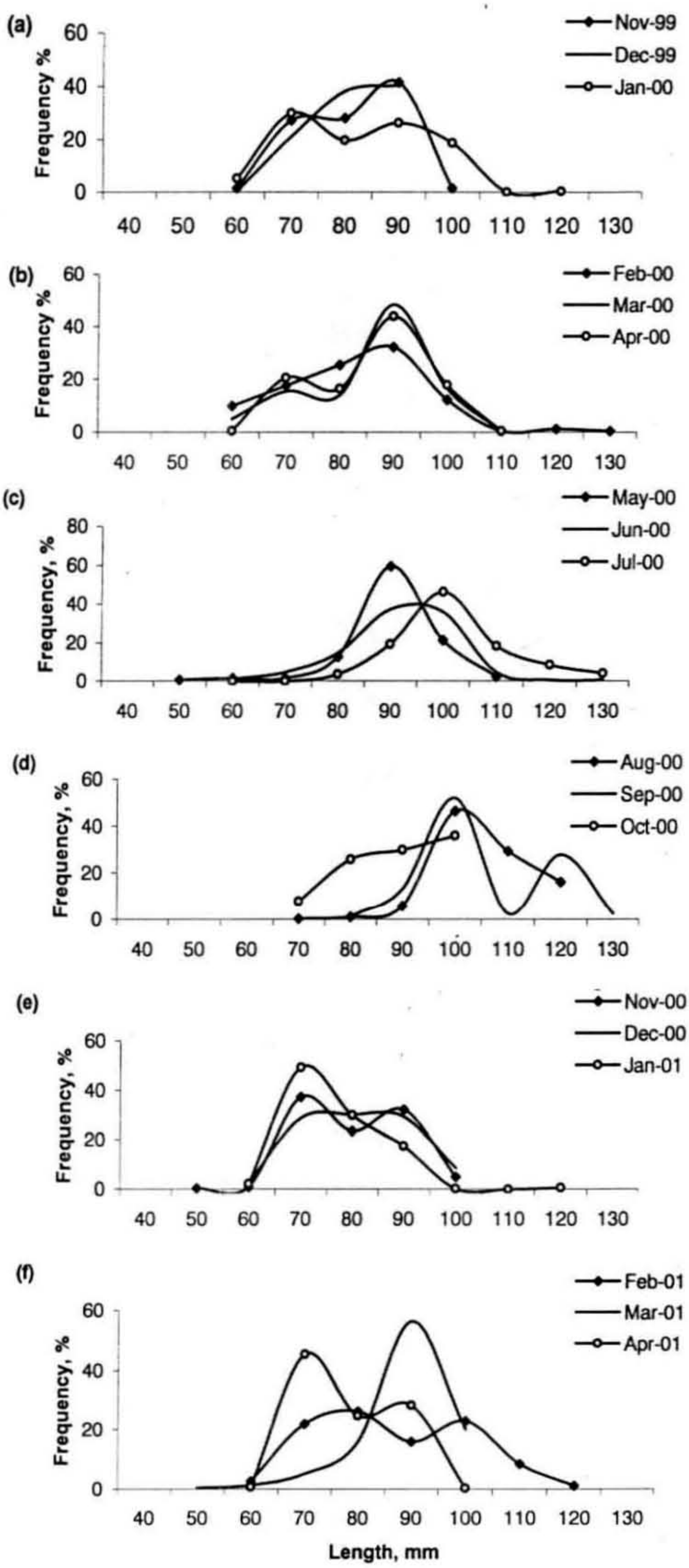


Fig. 5.24. (a to f) Length frequency of *M. monoceros* in sluice net from perennial farms

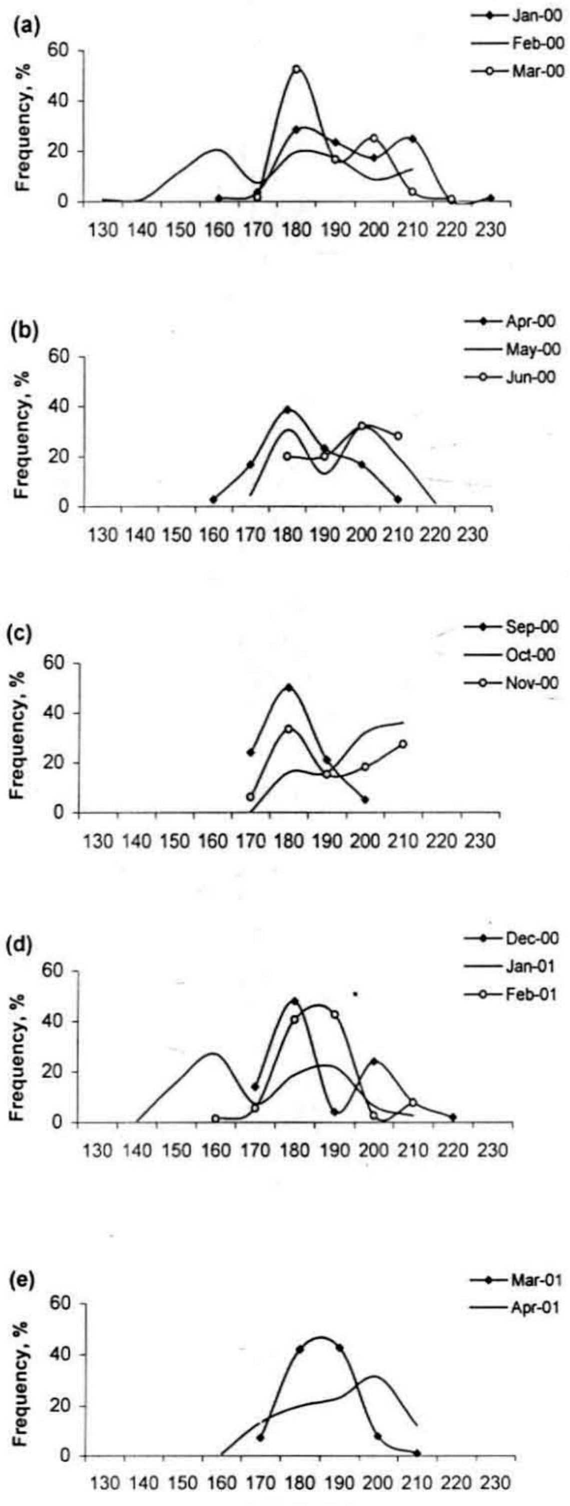


Fig. 5.25. (a to e) Length frequency of *P. monodon* in gill net from perennial farms

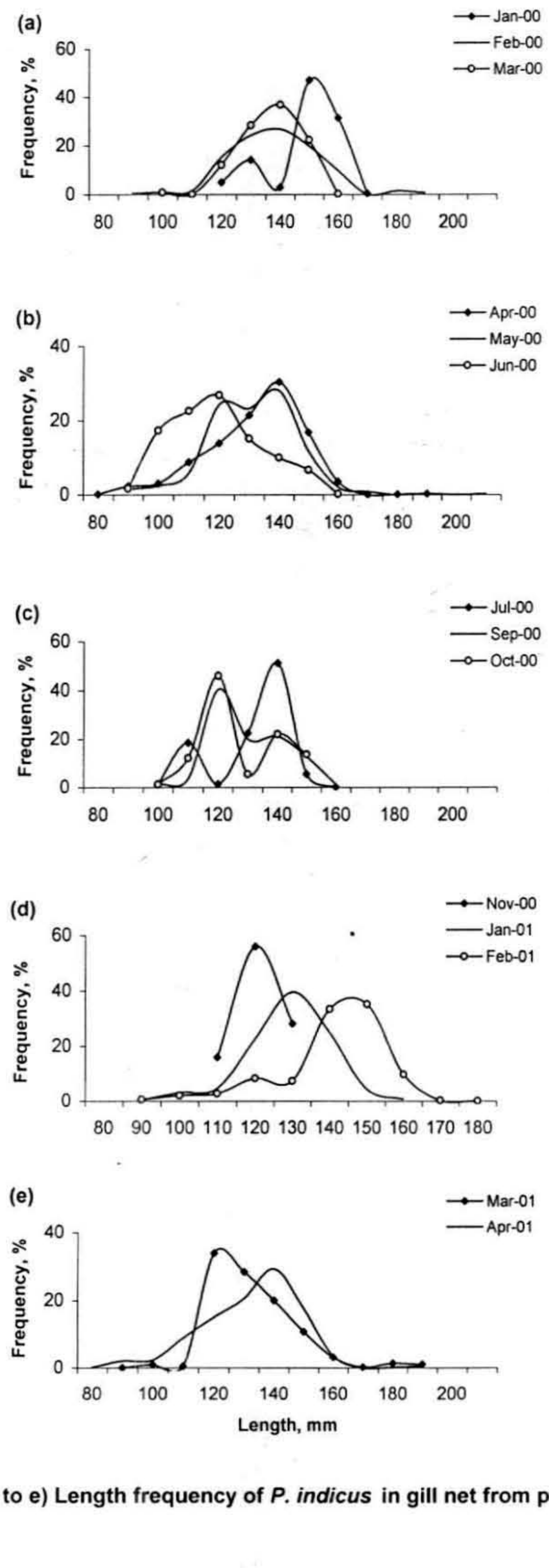


Fig. 5.26. (a to e) Length frequency of *P. indicus* in gill net from perennial farms

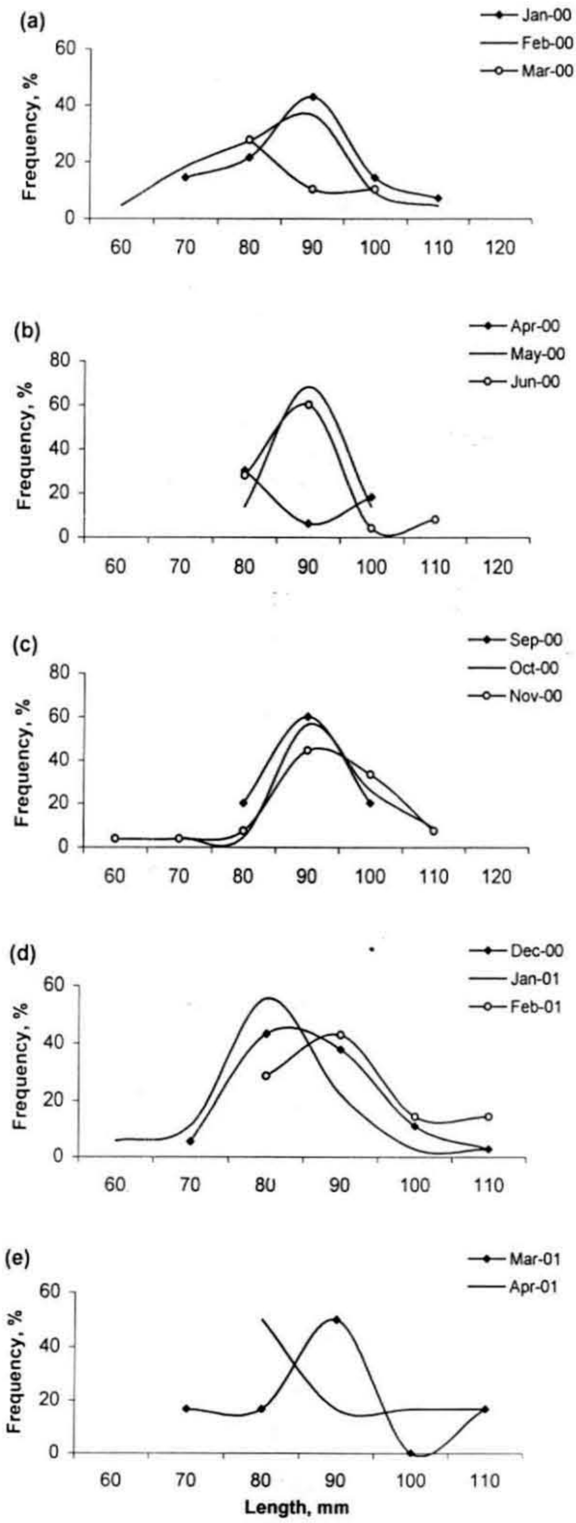


Fig. 5.27. (a to e) Length frequency of *M. dobsoni* in gill net from perennial farms

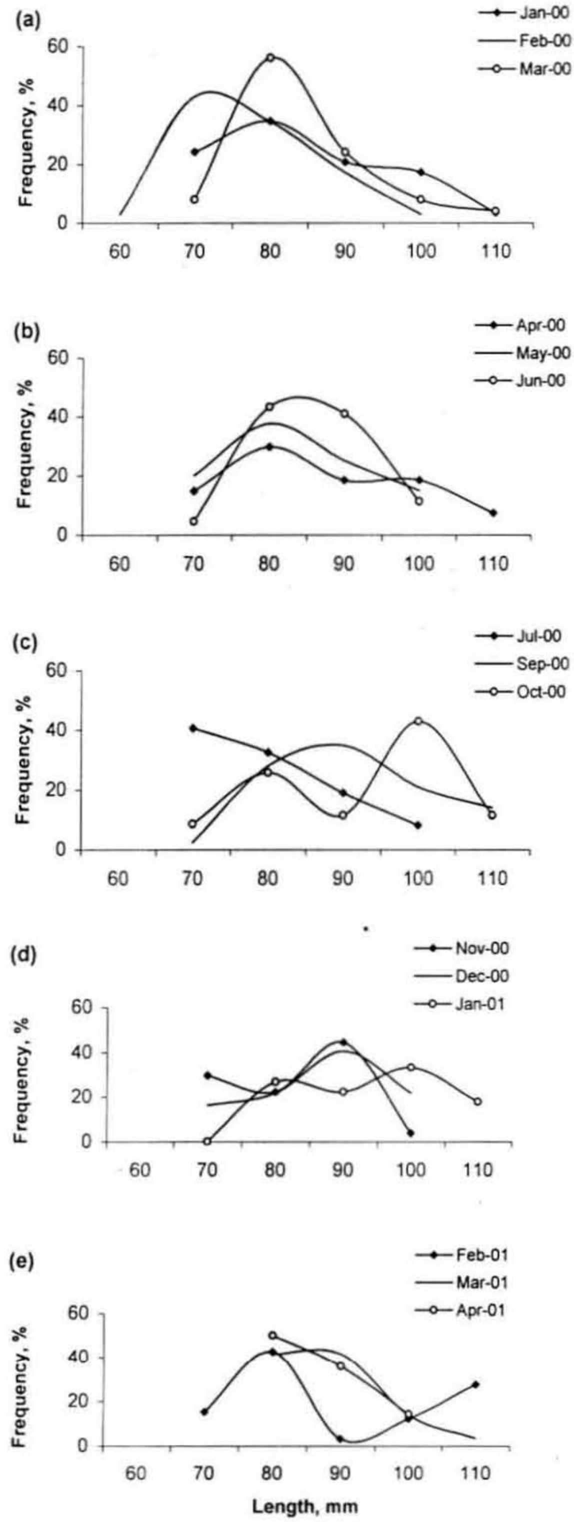


Fig. 5.28. (a to e) Length frequency of *M. monoceros* in gill net from perennial farms

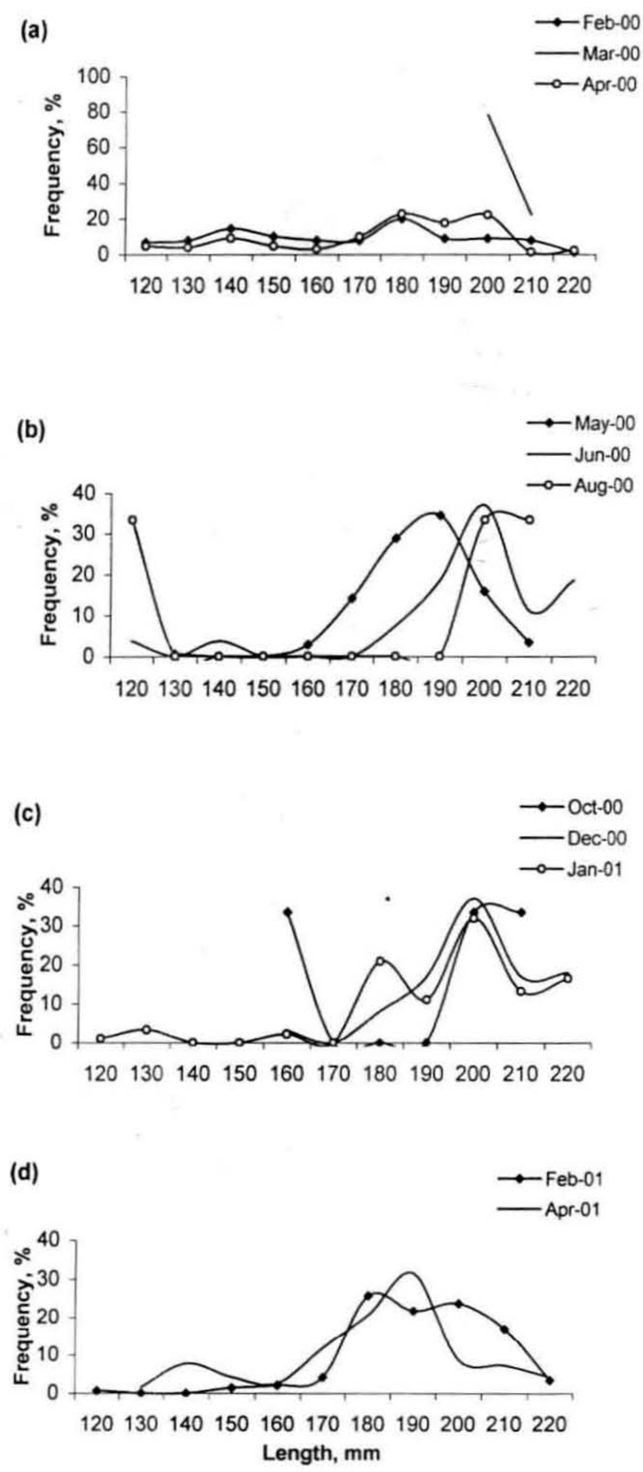


Fig. 5.29. (a to d) Length frequency of *P. monodon* in cast net from perennial farms

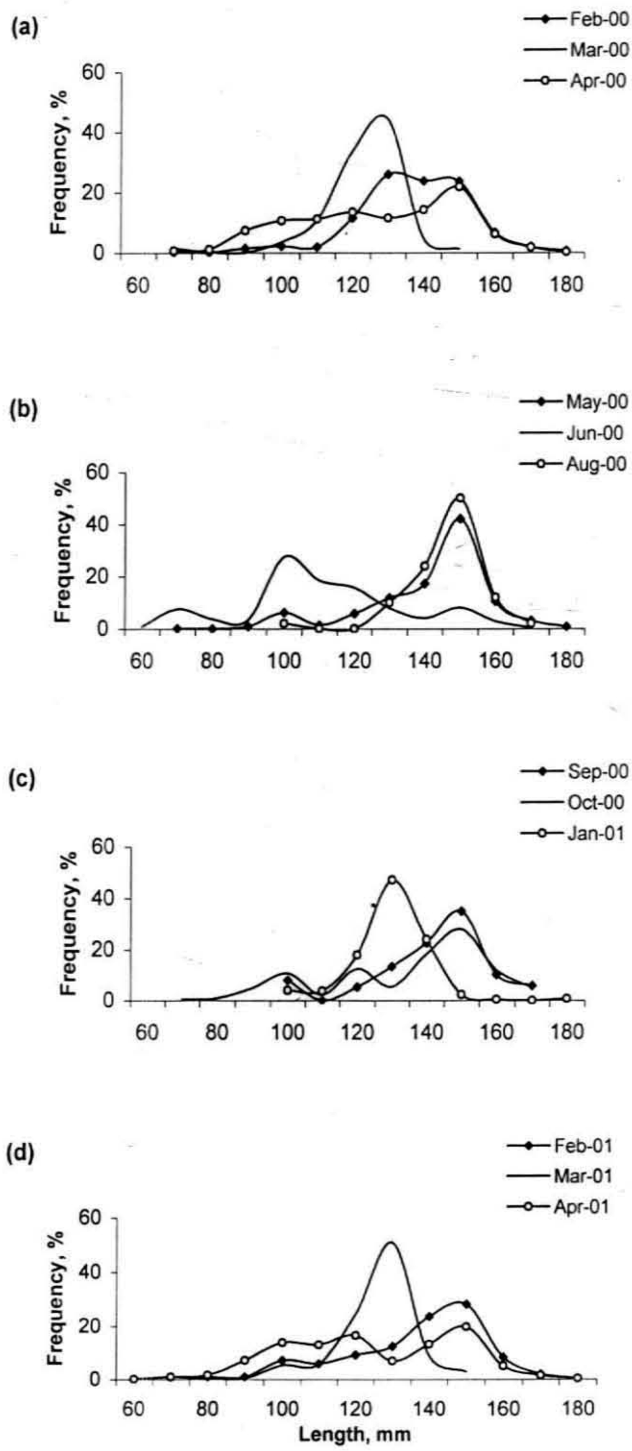


Fig. 5.30. (a to d) Length frequency of *P. indicus* in cast net from perennial farms

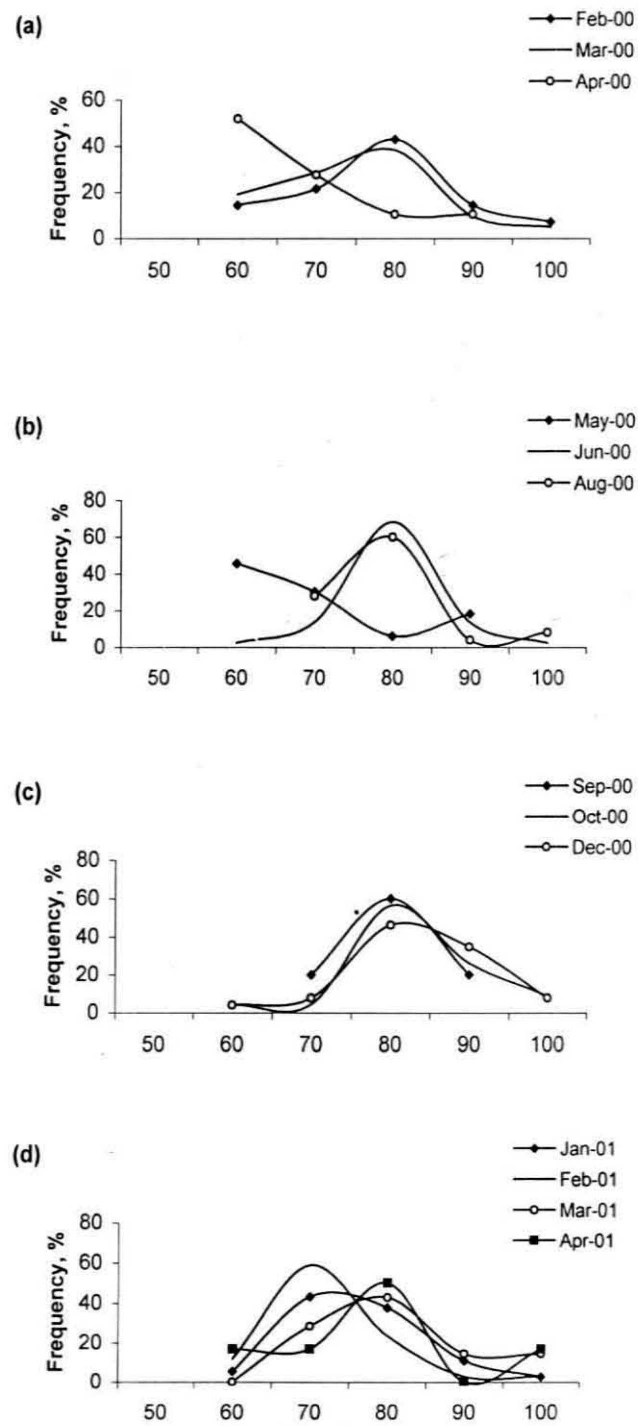


Fig. 5.31. (a to d) Length frequency of *M. dobsoni* in cast net from perennial farms

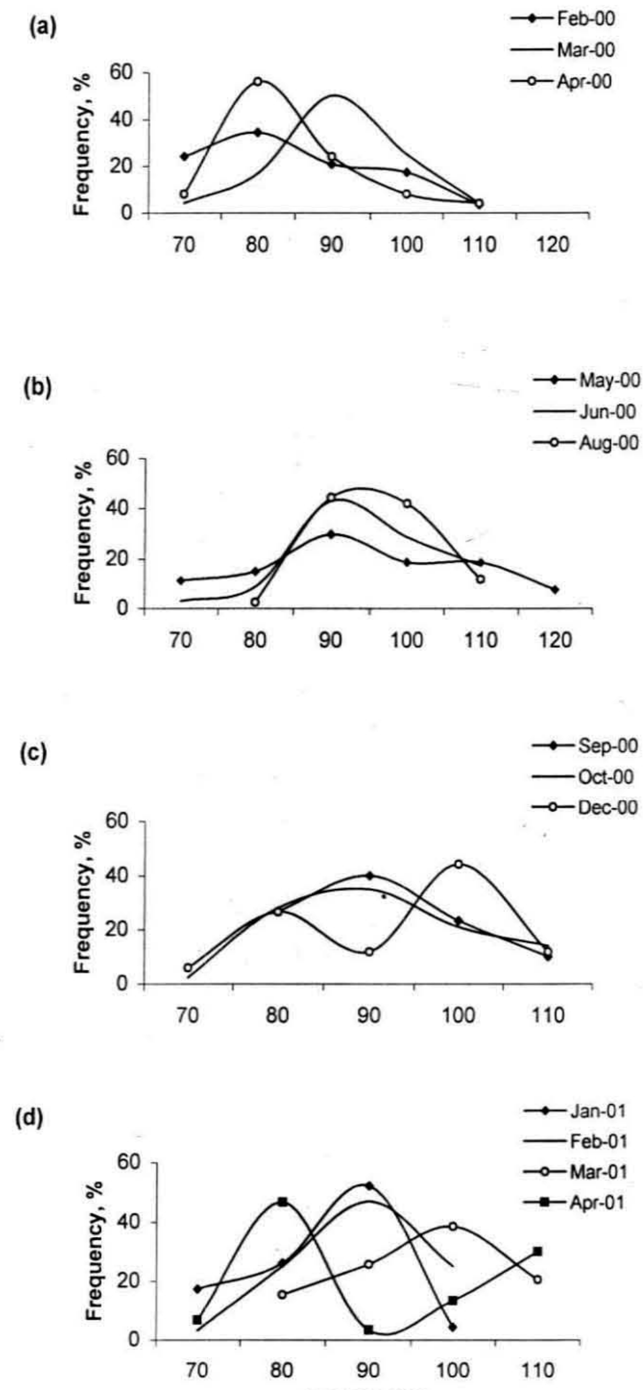


Fig. 5.32. (a to d) Length frequency of *M. monoceros* in cast net from perennial farms

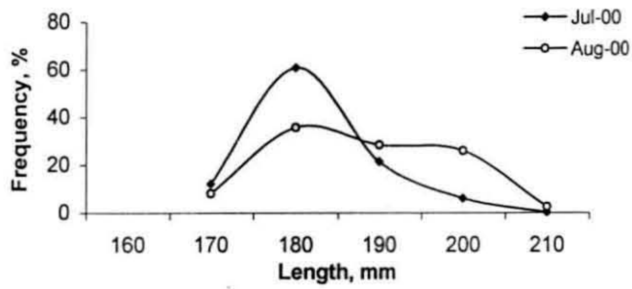


Fig. 5.33. Length frequency of *P. monodon* in hand picking from perennial farm

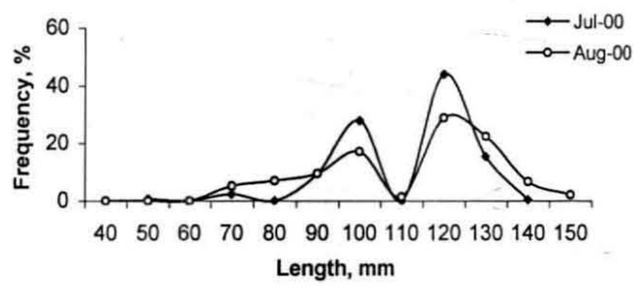


Fig. 5.34. Length frequency of *P. indicus* in hand picking from perennial farm

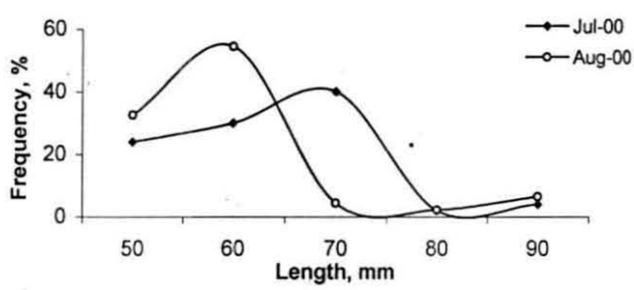


Fig. 5.35. Length frequency *M. dobsoni* in hand picking from perennial farm

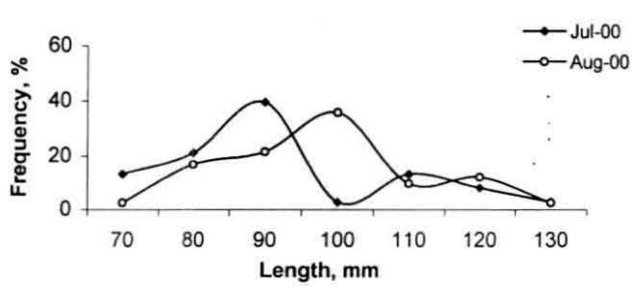


Fig. 5.36. Length frequency distribution of *M. monoceros* from perennial farm

5.3.3. Size composition and sex ratio

Length frequency distribution of the four major species of shrimps caught in different harvesting methods *viz.*, sluice net, gill net, cast net and handpicking for seasonal farms is given in Fig. 5.5. to 5.20. and for perennial farms in Fig. 5.21. to 5.36.. The month-wise size and sex ratio of the above four species harvested in different gears from seasonal farms and perennial farms are presented in Table 5.5. to 5.8. and Table 5.9. to 5.12., respectively. Month-wise average length of major species of shrimps harvested in different fishing gears from seasonal and perennial farms is shown in Table 5.13. and 5.14., respectively.

5.3.3.1. Seasonal farms

P. monodon: The size of the species ranged from 135-220 mm, majority of the shrimps belonged the length group 180-190 mm. The species- wise modal length from different harvesting systems in seasonal farms is given in Table 5.15. The size in case of sluice net ranged from 135 to 200 mm. The modal size of *P. monodon* in the sluice net was 162 mm. The size in the case of gill nets ranged from 150 to 210 mm and the majority of the shrimps belonged to the length class 180-190 mm and the modal length was 184 mm. In case of cast net, the length of the species ranged from 140 to 210 mm which was similar to gill net and the modal length was 182 mm. In hand picking the size of the species ranged from 130 to 220 mm and the modal length was 196 mm. This showed that the hand picked shrimps are of larger size compared to those caught by other methods as the fishers could selectively take the shrimps by hand. As hand picking is resorted to only in the final harvest, which is usually done only at the terminal period of shrimp culture, there is always a possibility of larger shrimps to remain in the farm due to further growth during the culture period. The other reason could be that the large specimens were not easily captured in the other nets as these burry below the mud and was quite accessible by hand picking.

P. indicus: The size of the species ranged from 55 to 155 mm and the majority of shrimp belonged to 115-125 mm size group in sluice net and the modal length was 120 mm. In case of gill nets, majority of shrimps belonged to 110-130 mm and the modal length was 130 mm. In cast net, majority of the shrimps belonged to 100-120 mm length class and the modal length was 112 mm and in hand picking the majority of the shrimps belonged to the length class 90-100 and the modal length was 95 mm. *P. indicus* is mostly caught by other fishing techniques and remaining small ones are harvested by hand picking.

M. dobsoni: The size of this species caught in sluice net ranged from 30 to 90 mm and the modal length was 52 mm. Most of the shrimps were belonging to the length class 50 to 60 mm. In gill nets, it ranged from 70 to100 mm and a modal length of 80 mm was observed. In cast nets, the size ranged from 30 to 90 mm and the modal length was 68 mm and in hand picking the size ranged from 30 to 90 mm and the modal length was 70 mm.

M. monoceros: The size of this species caught in sluice net ranged from 40 to 110 mm and the modal length was 85 mm. Most of the shrimps were belonging to the length class 80-90 mm. In gill nets, it ranged from 60 to 110 mm and a modal length of 84 mm was observed. In cast nets the size ranged from 60 to 110 mm and the modal length was 81 mm and in hand picking the size ranged from 70 to 110 mm and the modal length was 78 mm.

5.3.3.2. Perennial farms

P. monodon: The size ranged between 115 and 240 mm in sluice net, 130-226 mm in gill net, 120-230 mm in cast net and 160-215 mm in hand picking. The species wise modal length from different harvesting systems in perennial farms is given in Table 5.16. The modal lengths were 180, 185, 182, and 180 mm for different harvesting methods respectively, showing an increased modal length in gill net and cast net.

Table 5.16. Size range and modal length of major species of shrimps from different harvesting techinques in perennial farms

Harvesting techniques	*P. modonon*		*P. indicus*		*M. dobsoni*		*M. monoceros*	
	Size range (mm)	Modal length (mm)	Size range (mm)	Modal length (mm)	Size range (mm)	Modal length (mm)	Size range (mm)	Modal length (mm)
Sluice net	115-240	180.0	50-210	120.0	30-110	60.0	42-128	82.0
Gill net	130-226	185.0	85-252	140.0	60-119	80.0	42-130	84.0
Cast net	120-230	182.0	60-175	145.0	45-110	81.0	50-133	83.0
Hand picking	162-212	180.0	48-150	120.0	50-98	79.0	74-122	94.0

P. indicus: The size ranged between 50 and 210 mm in sluice net, 85-252 mm in gill net, 60-175 mm in cast net and 45-150 mm in hand picking. The modal lengths were 120, 140, 145, and 120 mm for different harvesting methods respectively, showing a similar increase in modal length in gill net and cast net as in the case of monodon. Smaller species measuring 50 mm generally appeared during June – July months.

M. dobsoni: The size ranged between 30 and110 mm in sluice net, 60-119 mm in gill net, 45-110 mm in cast net and 50-100 mm in hand picking. The modal lengths were 60, 80, 81, and 79 mm for the different harvesting methods sluice net, gill net, cast net and hand picking, respectively.

M. monoceros: The size ranged between 40 and 130 mm in sluice net, 40-130 mm in gill net, 50-135 mm in cast net and 75-135 mm in hand picking. The modal lengths were 82, 84, 83, and 94 mm for sluice net, gill net, cast net and hand picking respectively. Not much difference was observed in the modal lengths of *M. monoceros* among the different harvesting techniques.

The male and female ratio in seasonal farms was 1:1.3, 1:1.3, 1:1.1 and 1:1 and in perennial farms it was 1:1.3, 1:1.3, 1:1.2 and 1:1.1 in case of *P. monodon, P. indicus, M. dobsoni* and *M. monoceros* respectively, suggesting the dominance of females in the population.

In the both seasonal and perennial farms, It was difficult to estimate the growth rate by following the progression of modes in length frequency curves. This is mainly due to immigration of juveniles into the farms and regular fishing by filtration. Pillai and Krishnan (1998) also made similar observations in seasonal and perennial farms. A look into the size frequency graphs shows that the recruitment to the fishery in the case of all species is more or less continuous. The majority of the recruits brought into the field by the incoming tide do not seem to move out during the subsequent out going tide. They seek shelter in the paddy stocks and get burried in the mud and settle down in the new habitat for some period and move out probably after 5-6 weeks of growth (George *et al.*, 1968). This could be one of the reason for getting more or less same size shrimps in the sluice net in perennial farms. The quick progress of modal size seen during some months in perennial farms showed that the juveniles grew at a faster rate in this field. This has also been found for Cochin backwaters by Mohammed and Rao (1971). *P. indicus* grew at an average rate of 10.0 mm per month (George, 1974). In all the species irregular distribution of modes were observed in the size frequency curves for different months. Relatively larger size shrimps were observed in the perennial farms. This could be mainly because the perennial farms are generally vast and deep and the shrimps which enter the pond could stay for a longer time and therefore could attain larger size, whereas in the case of seasonal farms the time is limited to only 6 months. The smallest size observed in the present study was 65 mm in case of *P.* indicus in seasonal and perennial farms. This could be attributed to the practice for avoiding sluice net operations by the farmers if small sized *P. indicus* appear in the catches (Pillai and Krishnan, 1998) in order to allow them to grow to marketable size. The total catch in $kg.h^{-1}$ of different gear from the perennial farms was relatively less than that of the seasonal farms. The length frequency distribution of the species in different months from perennial farms showed a unimodal distribution in *M. dobsoni* in sluice nets. In the case of *P. indicus, M. dobsoni* and *M. monoceros* larger modal lengths were observed in gill nets and cast nets as compared to those caught in sluice net. This could be attributed to the fact that the mesh size used in the cast net and gill nets facilitated the escape of small shrimps and that these nets were operated in the last phase of the harvesting operations when majority of the shrimps available were of bigger size.

As the perennial farms are of much larger size and more deeper as compared to the seasonal farms, the shrimps in the perennial farms are not easily caught by filtration alone and therefore other fishing techniques like gill net, cast net, will have to be carried out regularly to harvest the shrimp.

CHAPTER - 6

CATCHING EFFICIENCY AND SELECTIVITY

6. CATCH EFFICIENCY AND SELECTIVITY

6.1. Introduction

Gill nets and cast nets are widely used for harvesting shrimps in the extensive and traditional shrimp culture farms. They are efficient and relatively inexpensive. Gill nets are among the most selective gear in terms of both species caught and the size range retained (Gulland, 1983).

A few studies have been carried out on the catch efficiency and selectivity of gill nets and trammel nets (Acosta and Apppledoorn, 1995; Thomas, *et al.*,1993). Losanes *et al.* (1992) has worked on the catch efficiency of entangling nets. Gill netting has been getting importance in recent years for the capture of large variety of penaeid shrimps. The catch efficiency of gill nets depends on the use of right materials having least thickness without reduction in strength, lesser visibility, softness, desired elasticity and knot strength. The colour of material, mesh size and hanging ratios also influence the efficiency of gill nets. (Clark, 1960). The selection of the best available material for specific purpose is very important as there is no ideal material to suit varied requirements. Comparative catch efficiency of nylon over cotton gill nets in reservoirs was done by Mathai and George (1972). Studies on the relative efficiency of PA monofilament and PA multifilament gill nets and trammel nets for penaeid shrimps have been carried out by Thomas *et al.* (2003) and (Klust, 1982). The efficiency of polyamide (PA) monofilament gill nets over PA multifilament has been reported by many (Steinberg, 1964; Shimozaki, 1964; Shon, 1978 and Radhalakshmi and Nayar, 1985.). However, Njoku (1991) reported that PA monofilament gill nets did not always perform better than multifilament gill nets.

Selectivity is defined as the ability to target and capture fish by species, size or sex or a combination of these during harvesting operations, allowing all incidental bycatch to be released unharmed. Bycatch included small or non targeted species and other living organisms encountered during harvesting. In order to have an optimum yield of a particular species and size group, it was highly necessary to determine the selectivity of the gear. By regulating the minimum mesh size of the gear, the minimum size of the target species to be caught could be more or less determined. It could be an important tool for effective management of fisheries.

Collins, (1882) studied the selective property of gill nets. However, a scientific approach on gill net selectivity was thought of by Baranov (1914). Work on selectivity of gill nets has been carried out by many workers (Baranov, 1948; Mc Combie, 1961: Mc Combie and Fry, 1960; Regier and Robertson, 1966; Mc Combie and Berst, 1969; Hamley and Regier, 1973; Yatsu and Watanabe, 1987; Karunasinghe and Wijayarantne, 1991; Reis and Pawson, 1992; Acosta and Appledoorn, 1995; Hodgson, 1927, 1933; Havinga and Deedler, 1949; Holt, 1963; Olsen, 1959; Nomura, 1961, Joseph and Sebastain, 1964; Sulochanan *et al.* 1968, 1975; Sreekrishna *et al.,* 1972; Panicker *et al.*, 1978; Shon, 1985; Mathai *et al.*, 1993; Salvanes, 1991). A comprehensive review of gill net selectivity was presented by Hamley (1975). Gill net, though relatively passive, is efficient in catching sparsely distributed fish. It is a highly selective gear and few fish are caught whose length differ from the optimum by more than 20 percent (Baranov, 1948) A proper mesh size aids in obtaining the maximum yield. (Kennedy, 1950; Peterson, 1954; Mc Combie, 1961). Studies on the selectivity of gill net for shrimps are scanty and are mostly related to comparative efficiency with respect to material difference and design aspects (Mathai *et al.*, 1990; George, 1991: Thomas *et al.*, 1993). Thomas *et al.* (2003) carried out studies on the length frequency distribution of *P. indicus*. Masuda and Matuda (1976) attempted to study the selectivity of Japanese prawns *P. japonicus*. George (1991) experimented on the length frequency distribution of *P. indicus*.

Gill nets are size and species selective. Thus a given net with a given mesh size can successfully catch fish of a certain size only, which are optimal for the net. With increasing deviation of the fish size from the optimum, the number of fish retained in the net decreases (Fridman, 1973). Gill net selectivity operates for a certain size range, small individuals pass though the mesh and larger ones cannot become enmeshed. This gives a bell shaped selectivity curve. Whereas in case of filtering gear, the larger the individuals the higher the percentage retained, which gives a sigmoid selectivity curve. The size selectivity can be estimated by different ways. Holt (1963) suggested that selection curves are bell shaped and show a normal distribution. He showed that natural logarithms of ratios of catches in numbers for two nets with slightly different mesh size having overlapping selection ogives, are linearly related to fish lengths. Mean selection length, selection factor, and selection range are to be estimated using statistical techniques. The optimum mesh size can be fixed according to the species, taking into consideration of the size at recruitment and the optimum size for exploitation. For simple gill nets, the selection curve has a descending slope on the right hand side. Baranov (1914) recognized three ways in which the fish may get caught in the gill net. (a) gilled where the mesh is around the fish just behind the gill cover (b) wedged, where the mesh is around the body as far as the dorsal fin and (c) entangled, where the fish is held in the net by teeth, maxillaries, fins or other projections, without necessarily penetrating the mesh. In the case of shrimps catching is mostly through enmeshing as shown in Plate. 6.1.

The use of bait, lures or attracting devices like light can increase the catch efficiency of fishing gear. Coconut wastes are used to attract the shrimp before the net is cast from boats (Suseelan, 1975). Light

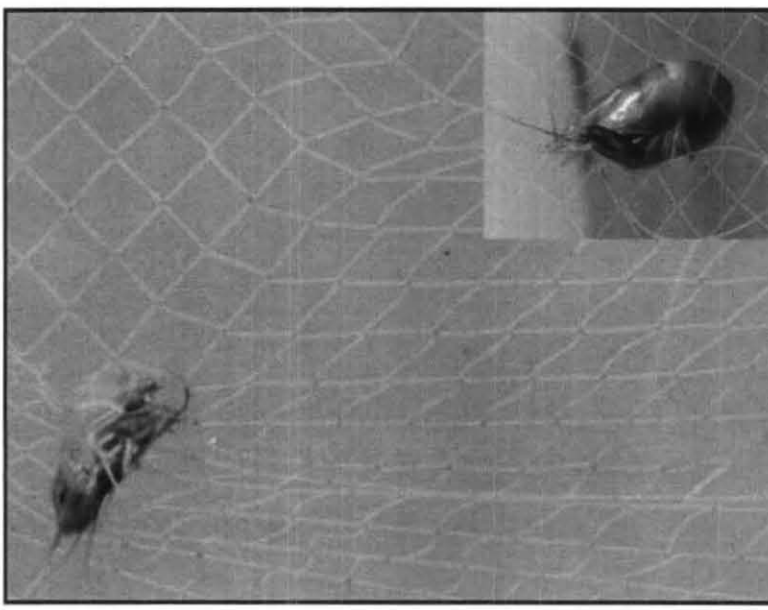


Plate 6.1. Enmeshed shrimps in monofilament gill net and a closer view of *P. indicus* shown in inset

and feeds are used in shrimp farms to lure shrimps and then are caught by using cast nets. However, much work has not been done on the efficiency of cast nets. George, *et al.* (1974) conducted a comparative study of several types of small scale fishing gear in the Cochin region in India. The gear compared were stake nets of 8 –12 mm mesh size, paddy filter nets with 9-11 mm mesh, lift nets of mesh size 9-17 mm, cast nets of mesh size 20-28 mm and gill nets of mesh size 30-35 mm. Six species of shrimp (*Penaeus indicus, P. semisulcatus, P. monodon, Metapenaeus dobsoni, M monoceros and M. affinis*) were analysed and the frequency histograms by size classes showed that, selectivity by size is achieved through mesh size. For *P. indicus*, 57 % of catches were smaller than 100 mm (TL), with stake nets, with paddy filter nets, lift nets, cast nets and gill nets, the figures were 75, 66, 64, and 62 %, respectively. Analyzing the catch composition of *P. indicus* by size classes showed very significant variations with cast nets of different mesh size. George, (1962) studied the size groups of *P. indicus* in the commercial catches of three different nets *viz.,* chinese dip net, stake net and cast nets. from the backwaters of Cochin.

Selectivity curves for spin shrimp juveniles (*Penaeus duorarum notialis*) were carried out in stow nets by Garcia and Lhomme (1977) using mesh size between 20 and 32 mm. Selectivity of barrier nets (Crosnier, 1965) and traps (LeReste, 1971) also have been studied for *P. indicus.*

Materials used for fabrication play a dominant role in any selective gear. Studies have been carried out on the comparative merits of synthetic nets over nets made of natural fibres in terms of catch. Superiority of nylon gill nets over cotton and linen is reported by Lawler (1950), Molin (1950,1956) Giesel (1953), Anon (1954), Shabtay (1956) and Pycha (1962). The commercial application of polyamide in gill nets was reported by Firth (1950). Catch efficiency of nets of different groups of synthetic fibres was carried out by Carrothers (1962), Honda and Osada (1964), Zaucha (1964) and Anon (1959 a, b), Klust (1959 and 1960) suggested that PA and PES fibre are suitable for gill net fabrication. PE gill nets were experimented along with nylon (Steinberg, 1964). PP material was recommended by Carter and West (1964) for gill nets and Pajot (1980a,b), and (Pajot and Das, 1981; 1984) attempted PE for substituting PA in large mesh gill nets.

Comparative studies on different materials for gill nets were also carried out by several workers in India. (George and Mathai, 1972; Radhalakshmi and Nayar, 1985; Khan *et al.*, 1975; Pillai *et al.*, 1989; Mohan Rajan *et al.,* 1991; George, 1991; Thomas, 2001).

The main objective of this study was to investigate the catch efficiency of gill nets and cast nets of different twine size and mesh size of PA monofilament and PA multifilament in culture systems and to determine the optimum selection length and selection factor for *P. indicus* in the case of gill nets.

6.2. Materials and Methods

The study was carried out in a 77.6 ha perennial shrimp aquaculture farm at Vypeen island for a period of 18 months from November 1999 to April 2001. The catch efficiency of monofilament gill nets versus multifilament gill nets, and monofilament versus multifilament cast nets were compared. The species composition, total length and weight of the catch caught in each net were recorded. Catch data were recorded separately for studying the relative catch efficiency of handpicking by women and men. The mean catch value was used in order to compensate for differences in sampling effort among the areas. In this study, gear efficiency is referred to the catch of a net for a given amount of effort. To study the significance of difference of total catch, *P. indicus*, total shrimp catch, and total fish catch, data were analysed statistically using single factor ANOVA for mesh size and twine size.

6.2.1 Gill nets

6.2.1.1 Gill net efficiency

In the case of gill nets the catch was standardized by converting the catch into catch per unit effort (CPUE) for an area of 1000 m^2 of webbing of gill net. Polyamide monofilament nets were of twine size 0.16 mm diameter having mesh size 28, 32, 34, 36, 38, 40, 44 mm and PA multifilament nets of twine size ranging from 210x1x2 with mesh size of 28, 32, 34, 36, 38, 40 and 44 mm and 210x1x3 with mesh size of 28, 32, 34, 36, 38 and 40 mm. All the nets rigged with hanging coefficient 0.50 were used for this study The design details of experimental gill nets are given in Table 6.1. The mesh size was determined by measuring the stretched meshes from randomly selected regions of the net with a centimeter scale (FAO, 1975) and the average values were taken. The total length of the individual shrimp from rostrum to tail tip was measured to the nearest mm (Sparre *et al.*, 1989). Operations were carried out at a depth of 2-4 m from a non motoroised wooden plank built traditional canoe of 6 m length overall. The gill nets were operated from 5 a.m.to 1 p.m. as bottom drift.

6.2.1.2. Gill net selectivity

The selectivity was estimated using the indirect method as suggested by Holt (1963). According to him the selection curves are bell shaped and that they can be described by the normal distribution for gilling and wedging. The data, from mesh size 28 mm was not analysed, as the data was insufficient.

Table 6.1. Design details of experimental gill nets

Material and twine size	Mesh size (mm)	Hanging ratio	Hung length: hung depth (m)	Floats specifications (mm)	No/unit	Sinkers specifications (g)	No/unit
PA monofilament 0.16 mm ø	28.0	0.50	50 x 1.8	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA monofilament 0.16 mm ø	32.0	0.50	50 x 2.0	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA monofilament 0.16 mm ø	34.0	0.50	50 x 2.3	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA monofilament 0.16 mm ø	36.0	0.50	50 x 2.3	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA monofilament 0.16 mm ø	38.0	0.50	50 x 2.4	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA monofilament 0.16 mm ø	40.0	0.50	50 x 2.4	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA monofilament 0.16 mm ø	44.0	0.50	50 x 2.5	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 2	28.0	0.50	50 x 1.8	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 2	32.0	0.50	50 x 2.0	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 2	34.0	0.50	50 x 2.3	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 2	36.0	0.50	50 x 2.3	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 2	38.0	0.50	50 x 2.4	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 2	40.0	0.50	50 x 2.4	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 2	44.0	0.50	50 x 2.5	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 3	28.0	0.5	50 x 1.8	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 3	32.0	0.5	50 x 2.0	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 3	34.0	0.5	50 x 2.3	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 3	36.0	0.5	50 x 2.3	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 3	38.0	0.5	50 x 2.4	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60
PA multifilament 210 x 1 x 3	40.0	0.5	50 x 2.4	50 x 10 PVC, cylindrical	35	25 g, lead, cylindrical	60

Thus:

$$S_L=\exp\left[-\frac{(L-Lm)^2}{2xs^2}\right] \quad \text{.......(1)}$$

Where S_L is the length based gear selectivity, L is length interval midpoint in mm, L_m is the optimum length for being caught in mm and s is the standard deviation of the normal distribution. The methodology involves calculation of the proportion between the number of fish of a particular length retained in gill nets of different mesh size.

$$\frac{Cb = \text{no. of fish of length l in a net with larger mesh size (m2)}}{Ca = \text{no of fish of same length l in a net with smaller mesh size (m1)}} \quad \text{.......(2)}$$

Calculation of log ratios for successive fish lengths

$$Y = \ln\left(\frac{Cb}{Ca}\right) \quad \text{.......(3)}$$

Regression analysis of the log ratios against the interval midpoint and expressed as

$$Y = \ln\left(\frac{Cb}{Ca}\right) = a + b \times L \quad \text{.......(4)}$$

Where Y is the natural logarithm of ratio of catches, L is the mid point of the length class, and a and b are constants.

The selection factor (SF) was calculated according to Jones (1984)

$$SF = \frac{-2xa}{b \times (m_1 + m_2)} \quad \text{.......(5)}$$

Where m_1 and m_2 are the mesh size of two gill nets with slightly different mesh size.

The optimal selection lengths (L_1 and L_2) in the two gill nets were calculated from the following equations.

$L1 = SF \times m_1$

$$L2= SF \times m_2 \quad \text{.......(6)}$$

The standard deviation (S) of each probability function was calculated (Jones, 1984) as follows:

$$S= \frac{(L_2 - L_1)^{0.5}}{b} \quad \text{.......(7)}$$

Using values for L_1, L_2 and S, the probability (P_1) of capture for a given length L in a gill net having a mesh size m_1 was calculated (Pauly, 1984).

$$P_1=\exp\left[\frac{-(L - L_1)^2}{(2S^2)}\right] \quad \text{.......(8)}$$

Similarly the probability (P_2) of capture for a given length L in a gill net having a mesh size m2 was calculated as

$$P_2=\exp\left[\frac{-(L - L_2)^2}{(2S^2)}\right] \quad \text{.......(9)}$$

Selectivity curves were drawn using probability of capture against each length class and the optimum selection length was calculated.

6.2.2. Cast nets

6.2.2.1 Cast net efficiency

In the case of cast nets the effort was calculated by number of times the gear had been cast, whether or not a catch was made. It was estimated that on an average a fisherman could make about 20 casts in one hour. The catch was standardized by converting the catch into catch per unit effort $kg.h^{-1}$ (CPUE). Polyamide monofilament cast nets of twine size ranging from 0.16 - 0.23 mm diameter with the bottom perimeter of 7-12 m^2 of mesh size 20, 24, 26, 28 30 and 32, mm and PA multifilament cast nets with twine size of 210x1x2 with the bottom perimeter of 7- 12 m^2 of the same mesh size as in the case of monofilament cast nets, were used for this study. The design details of experimental cast nets are given in Table 6.2.. The mesh size of the cast net and the length of species were measured as per the method used for gill nets. The cast nets were operated from 5 a.m. to 3 p.m. during the harvest period. Catch data from different mesh size and materials of cast nets were recorded separately for studying its relative catch efficiency. Data were also collected separately for the cast nets operated from shore and from canoe.

6.2.3. Handpicking

6.2.3.1. Handpicking efficiency

Hand picking was carried out by simultaneously by men and women from 8 a. m. to 2 p.m. Species-wise length were measured and catch per unit effort kg.hr^{-1} for shrimps and fish was found out separately for men and women from the same farm.

6.3. Results and Discussion

6.3.1. Gill net

Table 6.3. shows weight (kg) of total shrimps and fish landed in gill nets. *P. indicus* contributed 92.6 %, *P. monodon* 3.5 %, and other shrimps (*M. dobsoni* and *M. monoceros*) 3.2 % of the total shrimp catch. The fish catch comprised of mullets, *Milk fish, Pearl spot, tilapia*, catfishes, and a few other miscellaneous species like *Ambasis* sp., *Barbus* sp., *Cyprinoides* sp., *Anchoviella* sp., *Terapon* sp, and crab *Sylla serrata* together forming 13.4 % of the total catch. The catch (kg.h^{-1}) in 1000 m^2 of webbing in respect of *P. monodon, P. indicus* and other shrimps and total fish caught is given in Table 6.4.

Table 6.2. Design details of experimental cast nets

Material and twine size	Mesh size (mm)	Length (m)	Bottom diameter (m)	Specifications of twine	No/unit	Sinkers specifications (g)	No/unit
PA monofilament 0.16 mm ø	20.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.16 mm ø	22.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.16 mm ø	24.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.16 mm ø	26.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.16 mm ø	28.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.16 mm ø	30.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.16 mm ø	32.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.23 mm ø	20.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.23 mm ø	22.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.23 mm ø	24.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.23 mm ø	26.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.23 mm ø	28.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.23 mm ø	30.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA monofilament 0.23 mm ø	32.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA multifilament 210 x 1 x 2	20.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA multifilament 210 x 1 x 2	22.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA multifilament 210 x 1 x 2	24.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA multifilament 210 x 1 x 2	26.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA multifilament 210 x 1 x 2	28.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA multifilament 210 x 1 x 2	30.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80
PA multifilament 210 x 1 x 2	32.0	3.0	4-5	PA 210 x 6 x 3	21	20 g, lead, spindle	80

Table 6.3. Weight (kg) of shrimp captured in monofilament and multifilament gill nets of different mesh sizes

Catch (kg)	Mesh size (mm)						
	28.0	32.0	34.0	36.0	38.0	40.0	44.0
PA monofilament 0.16 mm ø							
P. monodon	5.5	3.8	4.6	2.5	3.0	1.2	5.0
P. indicus	58.0	76.7	104.7	93.7	88.6	80.1	68.5
Other shrimps	10.0	1.7	3.1	7.6	4.0	0.6	3.9
Total shrimps	73.5	82.2	112.4	103.8	95.6	81.9	77.4
Fish	38.0	33.3	7.6	17.2	6.9	5.6	7.0
Total catch	111.5	115.5	120.0	121.0	102.5	87.5	84.4
PA multifilament 210 x 1 x 2							
P. monodon	2.4	4.4	4.2	4.8	5.2	1.6	12.0
P. indicus	91.2	110.2	103.6	94.8	78.8	92.8	76.0
Other shrimps	2.8	5.4	2.1	5.5	5.4	0.9	1.9
Total shrimps	96.4	119.2	109.9	105.0	89.4	95.3	89.9
Fish	38.0	17.0	10.8	5.4	5.1	3.7	5.4
Total catch	134.4	136.2	120.7	110.4	94.5	99.0	95.3
PA multifilament 210 x 1 x 3							
P. monodon	2.8	3.6	4.2	3.6	3.5	1.6	-
P. indicus	96.2	95.2	103.6	87.2	88.0	91.8	-
Other shrimps	3.3	4.6	1.1	0.4	4.8	0.6	-
Total shrimps	102.3	103.4	108.9	91.2	96.3	94.0	-
Fish	36.0	32.8	10.8	15.6	8.0	4.7	-
Total catch	138.3	136.2	119.7	106.8	104.3	98.7	-

Table 6.4. Catch (kg) per 1000 m^2 of webbing in monofilament and multifilament gill nets of different mesh sizes

	Catch (kg)																						
Species	PA monofilament 0.16 mm Ø mesh size (mm)								PA multifilament 210 x 1 x 2 mesh size (mm)								PA multifilament 210 x 1 x 3 mesh size (mm)						
	28.0	32.0	34.0	36.0	38.0	40.0	44.0	Mean	28.0	32.0	34.0	36.0	38.0	40.0	44.0	Mean	28.0	32.0	34.0	36.0	38.0	40.0	Mean
P. monodon	4.5	0.2	3.1	1.8	1.6	0.5	1.7	1.9	2.0	0.0	3.6	2.6	5.7	1.8	11.1	3.8	2.4	0.0	6.4	2.2	2.5	1.9	2.6
P. indicus	45.0	60.6	73.0	63.3	58.8	33.9	41.3	53.7	77.2	90.9	89.1	72.5	70.8	70.9	55.2	75.2	82.1	115.5	123.8	103.9	64.0	86.5	96.0
Other shrimps	7.7	1.4	2.3	5.0	2.5	0.3	1.1	2.9	2.3	5.0	2.0	3.5	3.2	1.0	1.1	2.6	2.7	5.2	1.5	0.2	2.8	0.6	2.2
Total shrimps	57.2	64.9	78.4	70.2	62.9	34.7	44.0	58.9	81.5	99.9	94.7	78.6	79.7	73.8	67.3	82.2	87.3	125.2	131.7	106.4	69.3	88.9	101.5
Fish	29.4	28.7	4.9	7.3	4.7	2.4	3.9	11.6	32.2	14.0	9.4	2.8	4.3	2.8	3.9	9.9	30.6	38.2	11.8	7.4	5.7	4.5	16.4
Total catch	86.6	93.6	83.3	81.2	67.6	37.1	47.9	71.0	113.7	113.9	104.1	83.1	84.0	76.6	71.2	92.4	117.8	163.4	143.5	125.0	75.0	93.4	119.7

In this study it is assumed that the gill nets placed in juxtaposition perform uniformly and the percentage composition of different length groups obtained from different mesh size, represents the different groups in the stock. As there is continuous auto stocking of juveniles of shrimp species during the culture period into the filtration farms and addition of supplementary seeds of *P. indicus*, the stock in the farms represents different length groups.

6.3.1.1. Relative efficiency with regard to mesh size in gill nets

Comparison of catch was made between 6 different mesh size, viz. 28, 32, 34, 36, 38, and 40 mm. The catch details of 44 mm mesh size was not considered for the study as this mesh size was not represented in the PA multifilament 210x1x3 gill net. Mesh size 38 mm landed 17.9 % of the total experimental shrimp catch. The shrimp catch was less in 28 mm (11.7 %). The catch decreased as the mesh size increased from 34 to 40 mm. Considering the total catch of prawn and fish together, mesh size ranging from 32 to 36 mm showed better efficiency. In the case of multifilament gill nets much variation could not be seen in the shrimp catch between various mesh size. Maximum catch (18.4 % and 18.1 %) was observed in the nets with 32 mm and 34 mm mesh size, respectively. In order to test the significance of the difference in the catch efficiency, the variance for total catch, shrimp catch, catch of *P. indicus* and fish catch were analysed separately.

Table 6.5. gives ANOVA of total catch in different mesh size. There is significant difference between meshes as far as total catch is concerned ($P < 0.001$). LSD at 5 % level for mesh size is 0.1267. Mesh size 28, 32, and 34 mm are having significantly higher catch compared to other mesh size. This is mainly due to landing of substantial number of small size of fish and shrimps in the small mesh gill nets. Table 6.6. gives ANOVA of

fish catch in different mesh size. There is significant difference between meshes as far as fish catch is concerned ($P< 0.001$). LSD at 5 % level for mesh size is 0.2302. Mesh size 28 and 30 mm are having significantly higher catch than the rest. Significantly lower catches are seen in the gill net with mesh size 34, 36, 38 and 40 mm. ANOVA for testing the significant difference between the mesh and shrimp catch, mesh size and *P. indicus* showed no significance difference in the shrimp catch and catch of *P. indicus*, respectively.

6.3.1.2. Relative efficiency of PA monofilament and multifilament twines in gill nets

The relative catch efficiency of the three twine size, PA monofilament 0.16 mm diameter and PA multifilament 210x1x2 and PA multifilament 210x1x3 for gill nets were compared. All the twine size of PA gill nets used in the study caught all the species recorded. Fig. 6.1. gives the length frequency distribution of *P. indicus* caught in different twine size of gill nets. Total shrimp catch $kg.h^{-1}$ for 1000 m^2 of webbing was 58.9, 82.2 and 101.5 for PA monofilament 0.16 mm Ø, PA multifilament 210x1x2 and 210x1x3 gill nets, respectively, indicating that PA multifilament is more efficient than PA monofilament gill nets. To test whether there is significant difference in catch efficiency of the three twine size, catch in the experimental nets of different twine size, were analysed using single factor ANOVA, separately for total shrimps, catch of *P. indicus,* and fish catch.

Table 6.7. gives the ANOVA of total shrimp catch in different twine size. There is significant difference in total shrimp catch ($P<0.01$) when the twine size is taken into consideration. The twine 210x1x3 gave significantly higher shrimp catch compared to 0.16 mm PA twine size. Between the two multifilament twines there is no significant difference. Table 6.8. gives the ANOVA of total fish catch in different twine size. There is significant difference between fish catch and twine size. ($P<0.01$). The

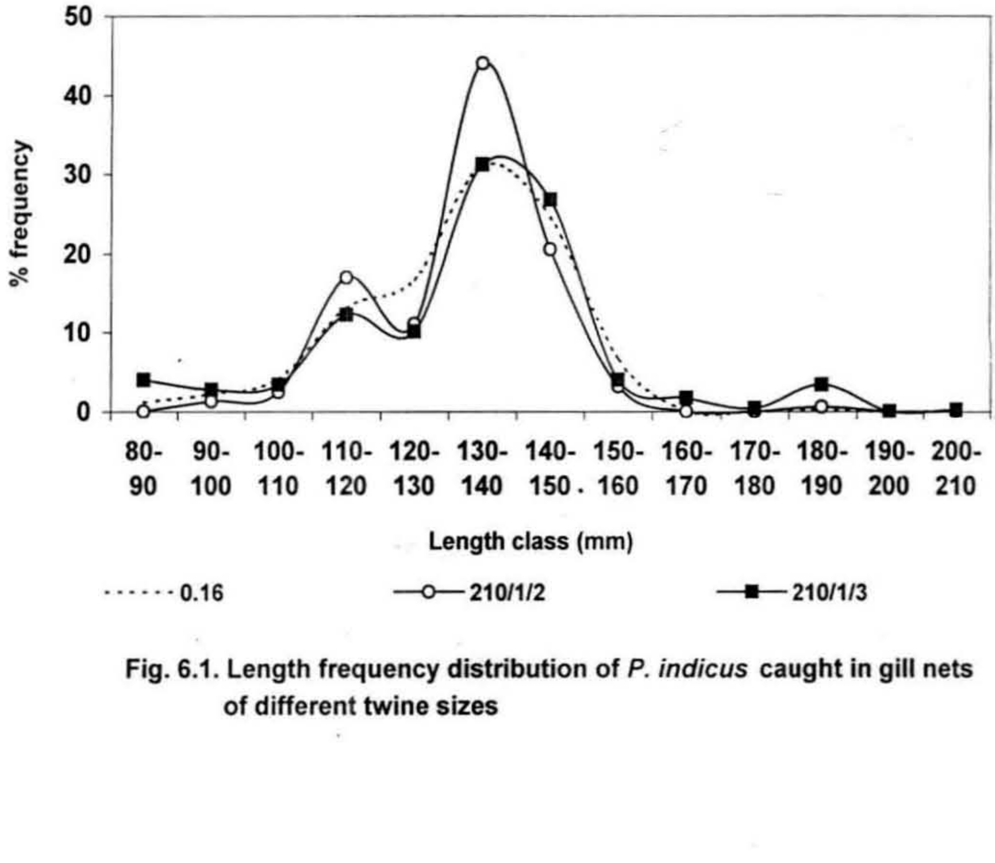


Fig. 6.1. Length frequency distribution of *P. indicus* caught in gill nets of different twine sizes

Table 6.5. Analysis of variance for different mesh size and total catch in gill nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between mesh sizes	5.217607	5	1.043521	8.665896	9.18E-08	2.239488595
Within mesh sizes	42.62763	354	0.120417			
Total	47.84523	359				
		LSD=	0.12671069			

Table 6.6. Analysis of variance for different mesh size and fish catch in gill nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between mesh sizes	203.7834	5	40.75669	102.546	1.21E-66	2.239488595
Within mesh sizes	140.6965	354	0.397448			
Total	344.48	359				
		LSD =	0.23020223			

Table 6.7. Analysis of variance for different twine size and total shrimp catch in gill nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between twine sizes	1.540284	2	0.770142	5.206919	0.005902	3.02101455
Within twine sizes	52.80295	357	0.147907			
Total	54.34324	359				
		LSD=	0.09929988			

Table 6.8. Analysis of variance for different twine size and fish catch in gill nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between twine sizes	11.16711	2	5.583553	5.980353	0.002788	3.02101455
Within twine sizes	333.3129	357	0.933649			
Total	344.48	359				
		LSD =	0.249486			

Table 6.9. Analysis of variance for different twine size and catch of *P. indicus.* in gill nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between twine sizes	1.912928	2	0.956464	5.328348	0.005246	3.02101455
Within twine sizes	64.08322	357	0.179505			
Total	65.99615	359				
		LSD=	0.10939378			

twines of diameter 0.16 mm and 210x1x3 PA gave significantly higher fish catch compared to 210x1x2 twine. Table 6.9. gives the ANOVA of catch of *P. indicus* in different twine size.

There was a significant difference in catch of *P. indicus* when the twine size was taken into consideration. ($P<0.001$). The twine 210x1x3 gave significantly higher shrimp catch compared to 0.16 mm and 210x1x2 twines. Between 0.16 mm and 210x1x2 twines there was no significant difference. It was observed that multifilament gill nets (210x1x2 and 210x1x3) caught more *P. indicus,* shrimps and fish in terms of total weight. The higher catch efficiency of PA multifilament gill nets compared to monofilament is in agreement with earlier reports. Njoku (1991) observed that multifilament nets captured more fish in terms of total weight. Baranov (1914) and Klust (1973) have testified to the gilling efficiency of multifilament nets. The weight of shrimp was higher for multifilament gill nets (650 kg) than for monofilament gill nets which landed (549 kg). This could be due to the fact that soft twisted PA multifilament twines, usually have very fine diameters, and they tend entangle the fish. The entangling ability of the multifilament netting has been described by Baranov (1976) as a basic advantage over the monofilament material.

6.3.1.3. Selectivity of P. indicus in gill nets

Table 6.10. gives the percentage frequency distribution of the number of *P. indicus* of each length class of 5 mm interval caught in each mesh size of the experimental gill nets. Six mesh size *viz.,* 32, 34, 36, 38, 40 and 44 mm were selected for the selectivity analysis. The modal size group of *P. indicus* caught in gill nets of 32, 34, 36, 38, 40 mm and 44 mm mesh size were 105-110, 110-115, 120-125, 120-125, 125-130 and 130-135 respectively. There is an increase in modal length with increasing mesh size. George (1991) observed modal length classes of *P. indicus* as 100-110, 110-

Table 6.10. Percentage length frequency of *P. indicus* caught in gill nets of different mesh sizes

Length class (mm)	Mesh size (mm)					
	32	34	36	38	40	44
	Percentage frequency					
80-85	0.39	1.00	0.80	0.00	0.00	0.00
85-90	7.44	3.01	0.96	1.00	0.68	0.00
90-95	9.00	3.21	0.96	0.66	0.68	0.56
95-100	11.35	7.21	6.24	1.00	1.02	1.13
100-105	9.59	6.61	11.20	1.66	0.85	0.94
105-110	17.42	14.83	6.72	2.49	2.04	3.20
110-115	9.20	22.04	9.92	6.80	3.91	3.77
115-120	11.55	12.22	7.04	12.77	6.46	1.32
120-125	9.00	10.82	18.24	26.87	11.22	0.94
125-130	1.96	6.41	12.96	17.08	28.57	12.99
130-135	8.81	4.41	12.32	19.40	22.11	19.77
135-140	0.98	1.60	8.16	5.97	12.76	16.95
140-145	1.37	2.00	1.44	1.49	3.57	16.76
145-150	1.17	1.80	1.12	0.17	1.70	13.75
150-155	0.78	1.80	0.96	1.66	2.38	6.21
155-160	0.00	1.00	0.64	1.00	1.02	0.75
160-165	0.00	0.00	0.32	0.00	1.02	0.94

120, and 140-150 mm in gill nets of mesh size 34, 38 and 50 mm. The modal length classes recorded by Thomas (2001) were 110-120 mm, 120-130 mm 120-130 mm and 150-160 mm in mesh size 34, 38, 40 and 50 mm respectively.

Fig. 6.2. shows the distribution of the points designated by ln(Ca/Cb) for the successive pairs of gill nets. Table 6.11. shows the number of *P. indicus* in length class caught in different mesh size. Table 6.12. gives the result of regression analysis between natural logarithms of relative catch ratio against class midpoint. The estimated selection factor and optimum selection lengths are given in Table 6.13. The optimal selection length increased gradually with increasing mesh size from 105 mm in 32 mm mesh size to 144 mm in 44 mm mesh size.

The estimated selectivity curve against the observed length frequency distribution is shown in Fig. 6.3. (a & b). The length of *P. indicus* showing the maximum probability of capture in 32 mm mesh size was 107.5 mm. This value gradually increased with increasing mesh size to 142.5 mm in 44 mm mesh size. The modal length class of the observed length frequency and the estimated optimum selection length coincided in 32 mm and 34 mm mesh size. This may be due to the suitability of the particular mesh size to the size class of *P. indicus* exposed to the nets. The mode of the observed length frequency deviated from the estimated mean selection length by 2.1 %, 3.2 %, 9.3 % lesser for the mesh size 38, 40 and 44 mm, respectively, and by 3.4 % higher for the mesh size 36 mm. The deviation may be due to varied size groups of *P. indicus* exposed or due to entanglement of individuals shrimps in the net. Comparison of the estimated optimum selection lengths of *P. indicus* for each mesh size was made against the marketable size to assess the suitability of the mesh size in harvesting *P. indicus* in a profitable way. The marketable size of *P. indicus* is

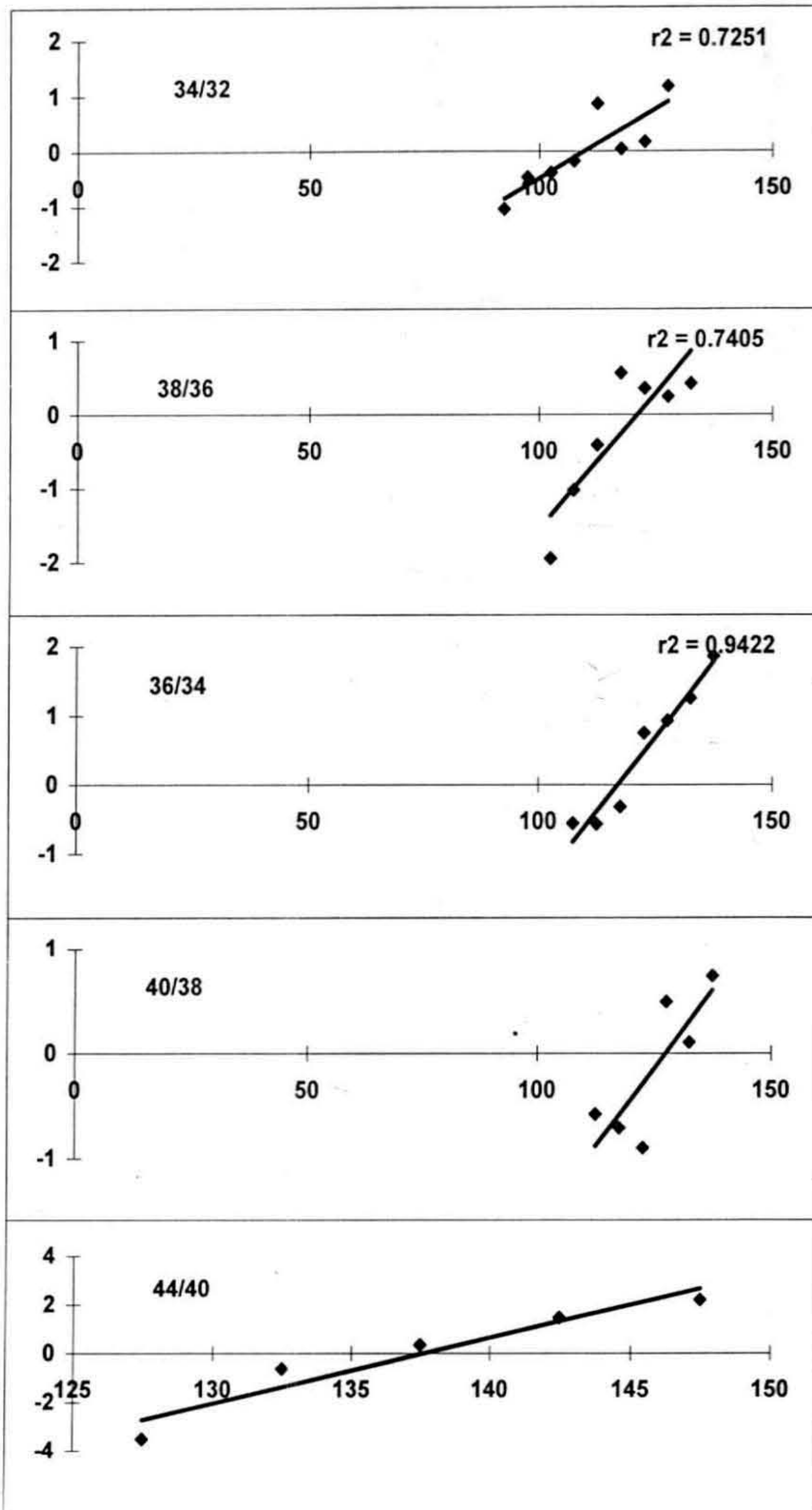


Fig. 6.2. Points ln(Cb/Ca) and lines of regression from the results of *P. indicus* catches with pairs of gill nets

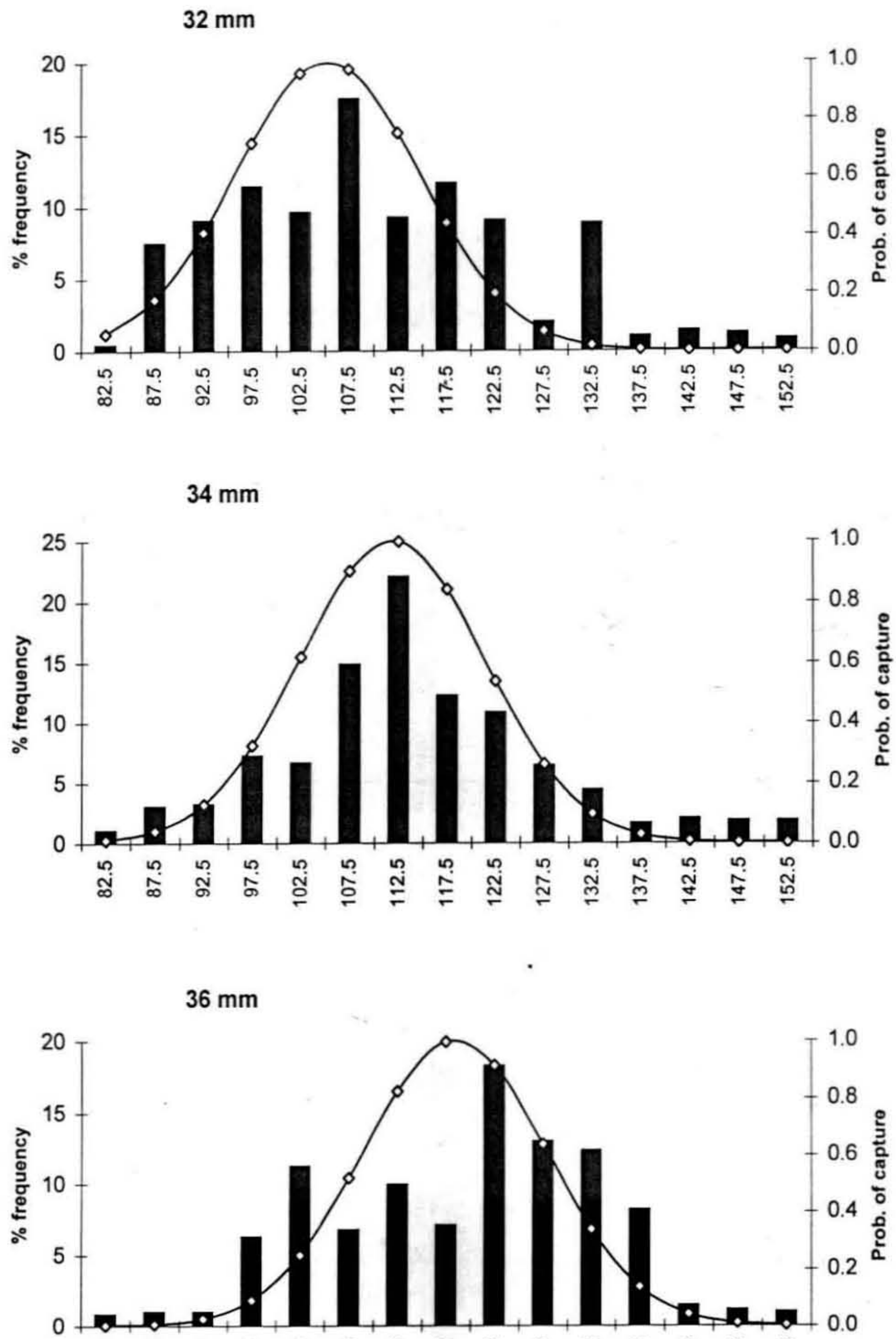


Fig. 6.3 (a) Observed and estimated selectivity curve of *P. indicus* caught in monofilament gill nets of different mesh sizes

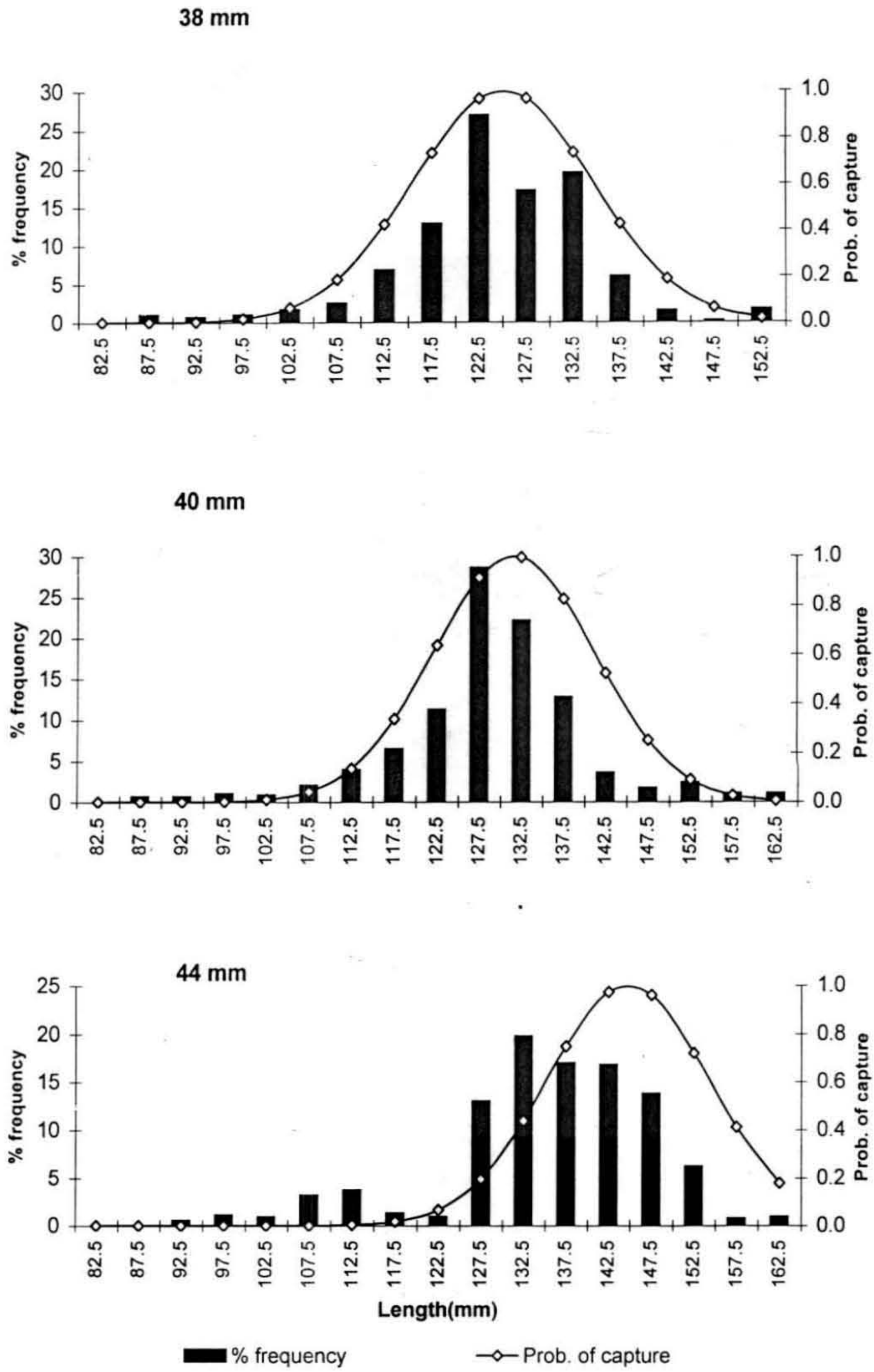


Fig. 6.3 (b) Observed and estimated selectivity curve of *P. indicus* caught in monofilament gill nets of different mesh sizes

Table. 6.11. **Number of *P. indicus* caught in monofilament gill nets of different mesh sizes**

Mid point of length class (mm)	Mesh size (mm)						Total
	32	34	36	38	40	44	
82.5	2	5	5	0	0	0	12
87.5	38	15	6	6	4	0	69
92.5	46	16	6	4	4	3	79
97.5	58	36	39	6	6	6	151
102.5	49	33	70	10	5	5	172
107.5	89	74	42	15	12	17	249
112.5	47	110	62	41	23	20	303
117.5	59	61	44	77	38	7	286
122.5	46	54	114	162	66	5	447
127.5	10	32	81	103	168	69	463
132.5	45	22	77	117	130	105	496
137.5	5	8	51	36	75	90	265
142.5	7	10	9	9	21	89	145
147.5	6	9	7	1	10	73	106
152.5	4	9	6	10	14	33	76
157.5	0	5	4	6	6	4	25
162.5	0	0	2	0	6	5	13
Total numbers	543	533	661	641	628	575	3357

Table 6.12. Results of the regression analysis between natural logarithms of relative catch ratio against class midpoint for *P.indicus*

Mesh size combination (mm)	Intercept	Slope	Regression coefficient
32-34	-5.4991	0.0501	0.7251
34-36	-10.1699	0.0869	0.9422
36-38	-8.9865	0.0743	0.7405
38-40	-7.5581	0.0593	0.6675
40-44	-37.1312	0.2698	0.9211

Table 6.13. Selectivity estimates of *P. indicus* for gill nets of different mesh sizes

Mesh size (mm)	Optimum selection length (mm)	Selection factor	Number of shrimps
32	105.3	3.33	543
34	111.9	3.34	533
36	118.4	3.27	661
38	125.0	3.27	641
40	131.6	3.28	628
44	144.8	3.29	575

115 mm and above which comes under the 210 count headless and fetches better price. According to the estimated selection of gill nets for *P. indicus*, nets of mesh size 32 and 34 mm retained 64.4 % and 57.9 % of *P. indicus* whose total length is less than 115 mm whereas the mesh size 36, 38, 40 and 44 mm retained less than 50 % of *P. indicus* whose total length is less than 115 mm. As harvesting of shrimps is done frequently in the perennial farms, mesh size larger than 34 mm can be used in the initial harvesting stages, allowing the smaller shrimps to grow in the pond and attain the commercial size to make profit. However, during the final harvest all the mesh size can be used, as the primary objective is to harvest all the shrimps irrespective of its size before the lease period is completed. It can be seen from Table 6.3. that the weight of the catch decreases as the mesh size increases. As the fishermen who harvest the shrimps are paid according to the weight of the catch and not the length, they tend to use gill nets of smaller mesh size ranging from 28 to 36 mm.

6.3.2. Cast net

Table 6.14. shows weight (kg) of shrimp captured in monofilament and multifilament cast nets of different mesh size. *P. indicus* contributed 92.9 % *P. monodon 3.5* % and other shrimps 3.6 % of the total shrimp catch which contributed 85.6 % of the total catch in cast nets. 14.4 % of the total catch was represented by miscellaneous fishes like *Etroplus sp.*, *Tilapia sp.*, catfishes, and *Ambasis* sp. The catch $kg.h^{-1}$ of *P. monodon* and *P. indicus* and other shrimps and total fish caught is given in Table 6.15.

6.3.2.1. Relative efficiency with regard to mesh size in cast nets

In cast nets also comparison of catch was made among 6 different mesh size, *viz.*, 20, 24, 26, 28, 30 and 32 mm. Fluctuations in the

Table 6.14. Weight (kg) of shrimp captured in monofilament and multifilament cast nets of different mesh sizes

Catch (kg)	Mesh size (mm)					
	20.0	24.0	26.0	28.0	30.0	32.0
PA monofilament 0.16 mm ø						
P. monodon	0.7	1.0	0.4	0.9	0.6	4.0
P. indicus	15.2	18.5	19.8	23.6	15.0	17.4
Other shrimps	2.7	1.7	0.9	1.1	1.7	1.7
Total shrimps	18.6	21.2	21.1	25.6	17.3	23.1
Fish	2.3	10.4	6.6	4.4	2.1	2.1
Total catch	20.9	31.6	27.7	30.0	19.4	25.2
PA monofilament 0.20 mm ø						
P. monodon	1.0	1.8	1.0	1.5	1.5	3.7
P. indicus	21.2	15.0	49.3	36.0	22.9	39.5
Other shrimps	3.5	2.5	1.9	1.7	0.5	0.7
Total shrimps	25.7	19.3	52.2	39.2	24.9	43.9
Fish	3.2	5.9	6.6	8.0	3.8	9.1
Total catch	28.9	25.2	58.8	47.2	28.6	53.0
PA multifilament 210 x 1 x 2						
P. monodon	1.7	2.0	2.4	1.3	0.4	0.8
P. indicus	25.8	17.4	29.8	23.1	21.4	33.1
Other shrimps	6.2	0.8	1.5	0.6	0.3	0.9
Total shrimps	33.7	20.2	33.7	24.9	22.1	34.8
Fish	19.3	2.0	0.5	6.0	2.3	10.2
Total catch	52.9	22.2	34.2	30.9	24.4	45.0

Table 6.15. Catch kg.h^{-1} in monofilament and multifilament cast nets of different mesh sizes

Catch (kg)																					
Species	PA monofilament 0.16 mm Ø mesh size (mm)							PA monofilament 0.20 mm Ø mesh size (mm)							PA multifilament 210 x 1 x 23 mesh size (mm)						
	20.0	24.0	26.0	28.0	30.0	32.0	Mean	20.0	24.0	26.0	28.0	30.0	32.0	Mean	20.0	24.0	26.0	28.0	30.0	32.0	Mean
P. monodon	0.4	0.5	0.2	0.5	0.3	2.0	0.4	0.5	1.8	3.6	0.8	1.2	2.5	0.4	1.2	1.0	1.4	1.5	0.4	0.6	0.3
P. indicus	9.7	9.3	9.9	11.8	7.5	8.7	1.8	10.6	15.0	81.1	18.0	19.3	29.5	3.3	18.9	8.7	17.8	25.0	11.8	20.6	2.5
Other shrimps	1.6	0.9	0.5	0.6	0.9	0.9	0.3	1.8	2.5	4.1	0.9	0.4	0.7	0.3	5.0	0.4	0.8	0.6	0.3	0.6	0.5
Total shrimps	11.7	10.6	10.6	12.8	8.7	11.6	2.1	12.9	19.3	88.8	19.6	20.8	32.7	3.7	25.1	10.1	19.9	27.1	12.5	21.8	2.8
Fish	1.3	5.2	3.3	2.2	1.1	1.1	0.6	1.6	5.9	12.3	4.0	3.0	6.8	0.8	12.0	1.0	0.3	6.0	1.2	6.7	1.2
Total catch	13.0	15.8	13.9	15.0	9.7	12.6	2.6	14.5	25.2	101.0	23.6	23.8	39.5	4.4	37.1	11.1	20.2	33.1	13.7	28.5	3.5

catch were observed in different mesh size. Mesh size 20 mm, 26 mm 28 and 32 mm showed higher total catch than 24 and 30 mm mesh size.

Table 6.16. gives ANOVA of total catch in different mesh size. There is significant difference between different mesh size as far as total catch is concerned. (P< 0.001). LSD at 5 % level for mesh size is 0.2344. Mesh size 24 mm and 30 mm are having significantly lower catch than 20, 26, 28 and 32 mm mesh size. There is no significant difference in the total catch between 20, 26, 28 and 32 mm mesh size. The total catch was more in the smaller mesh size mainly due to catch of large number of other small sized shrimps (*M. monoceros* and *M. dobsoni*) and miscellaneous fish (*Ambasis* sp) which usually gets gilled in the mesh in large numbers. The catch was higher in 32 mm mesh size due to landings of more number of large sized *P. monodon* and *P. indicus* compared to other mesh size. Table 6.17. gives ANOVA of shrimp catch in different mesh size. There is significant difference between meshes and shrimp catch (P<0.001). Mesh size 26, 28 and 32 mm give significantly higher catch compared to other mesh size. However, between 26, 28 and 32 mm there is no significant difference in catch. Table 6.18. gives ANOVA of catch of *P. indicus* in different mesh size. There is significant difference in the catch of *P. indicus* in different mesh size (P<0.001). Mesh size 26, 28 and 32 mm gives significantly higher catch than the other mesh size. However, between 26, 28 and 32 mm there is no significant difference. Table 6.19. gives ANOVA of fish catch in different mesh size. There is significant difference in the catch of fish between the mesh size of cast net (P<0.001). Mesh size 24 and 28 mm gives significantly higher catch than the rest. However, between 24 and 28 mm there is no significant difference.

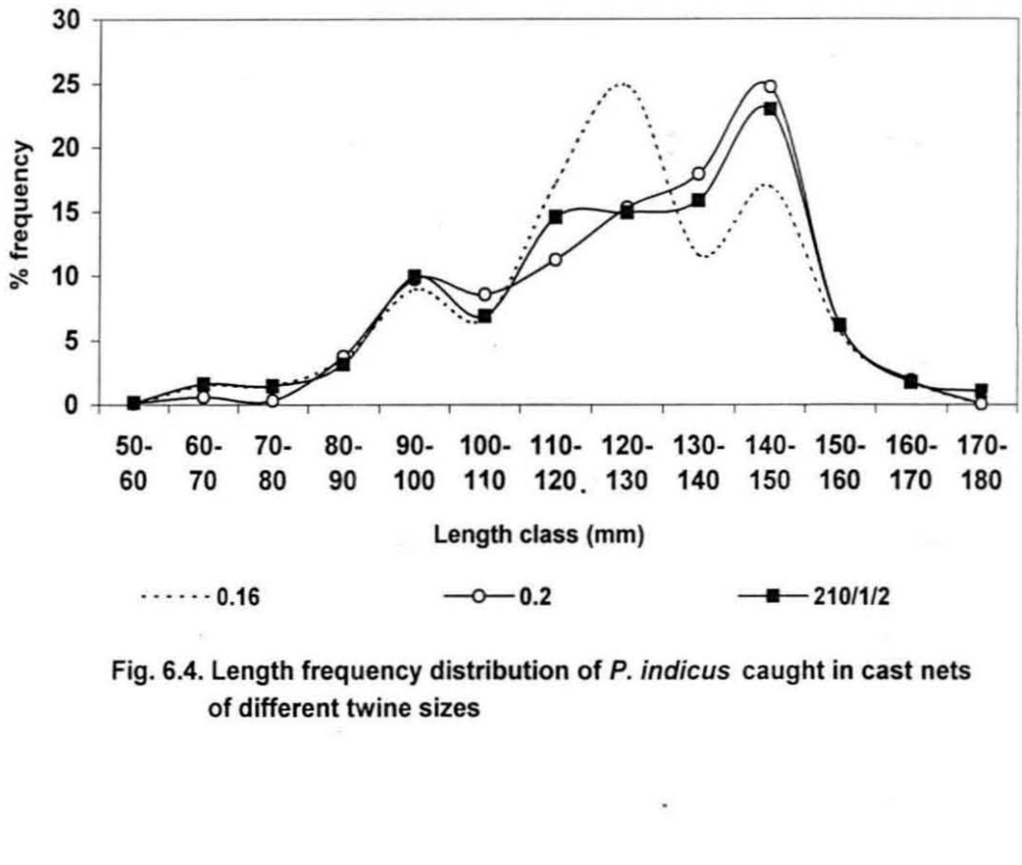


Fig. 6.4. Length frequency distribution of *P. indicus* caught in cast nets of different twine sizes

Table 6.16. Analysis of variance for different mesh size and total catch in cast nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between mesh sizes	6.652126	5	1.330425	6.456658	1.568E-05	2.26606289
Within mesh sizes	35.85353	174	0.206055			
Total	42.50565	179				
		LSD =	0.2344			

Table 6.17. Analysis of variance for different mesh size and shrimp catch in cast nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between mesh sizes	7.375336	5	1.475067	8.276212	4.895E-07	2.26606289
Within mesh sizes	31.01197	174	0.17823			
Total	38.38731	179				
		LSD =	0.218			

Table 6.18. Analysis of variance for different mesh size and catch of *P. indicus* in cast nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between mesh sizes	9.17247	5	1.834494	10.4147	9.355E-09	2.26606289
Within mesh sizes	30.64917	174	0.176145			
Total	39.82164	179				
		LSD =	0.2167			

Table 6.19. Analysis of variance for different mesh size and fish catch in cast nets

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between mesh sizes	22.63764	5	4.527528	7.513622	2.072E-06	2.26606289
Within mesh sizes	104.8482	174	0.602576			
Total	127.4859	179				
		LSD =	0.4009			

6.3.2.2. *Relative efficiency of PA monofilament and multifilament twines in cast nets*

In case of cast nets PA monofilament of 0.16 mm diameter, and 0.20 mm diameter and PA multifilament 210x1x2 were compared for relative efficiency. Fig. 6.4. gives the length frequency distribution of *P. indicus* caught in different twine size of cast nets. Total shrimp catch in $kg.h^{-1}$ was 2.1, 3.7 and 2.8 in nets of PA monofilament 0.16 mm diameter, and 0.20 mm diameter and PA multifilament 210x1x2 respectively.

Table 6.20. gives the ANOVA of total catch in different twine size. There was significant difference between total catch in nets of different twine size. ($P<0.001$). The 0.20 mm twine size and 210x1x2 gave significantly higher total catch compared to 0.16 mm twine. However, between 0.2 mm and 210x1x2 there was no significant difference at 5% level. Table 6.21. gives the ANOVA of total shrimp catch in different twine size. There was a significant difference between total catch and twine size. ($P<0.001$). Nets of twine size 0.20 mm diameter and 210x1x2 give significantly higher shrimp catch compared to 0.16 mm twine. However, between 0.20 mm and 210x1x2 there was no significant difference. Table 6.22. gives the ANOVA of catch of *P. indicus* in different twine size. There was a significant difference between catch of *P. indicus* in nets of different twine size. ($P<0.001$). Nets of twine size 0.20 mm diameter and 210x1x2 gave significantly higher catch of *P. indicus* compared to 0.16 mm diameter. Between 0.20 mm and 210x1x2 there was no significant difference. Table 6.23. gives the ANOVA of catch of fish in different twine size. There was significant difference between fish catch in nets of different twine size. ($P<0.001$). Nets of twine size 0.20 mm diameter and 210x1x2 gave significantly higher catch of fish compared to 0.16 mm twine. Between 0.2 mm and 210x1x2 there was no significant difference. In all the cases it was observed that 0.20 mm and 210x1x2 showed significantly higher catch than

Table 6.20. Analysis of variance for different twine size and total catch in cast nets

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between twine sizes	4.258875	2	2.129438	9.854698	8.752E-05	3.0470062
Within twine sizes	38.24678	177	0.216083			
Total	42.50565	179				
		LSD =	0.1697			

Table 6.21. Analysis of variance for different twine size and shrimp catch in cast nets

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between twine sizes	4.628522	2	2.314261	12.13385	1.152E-05	3.0470062
Within twine sizes	33.75879	177	0.190728			
Total	38.38731	179				
		LSD =	0.1595			

Table 6.22. Analysis of variance for different twine size and catch of *P. indicus* in cast nets

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between twine sizes	5.194343	2	2.597171	13.27564	4.246E-06	3.0470062
Within twine sizes	34.62729	177	0.195634			
Total	39.82164	179				
		LSD =	0.1615			

Table 6.23. Analysis of variance for different twine size and fish catch in cast nets

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between twine sizes	18.06277	2	9.031387	11.77527	1.581E-05	3.0470062
Within twine sizes	135.7553	177	0.766979			
Total	153.8181	179				
		LSD =	0.3178			

0.16 mm indicating comparatively thicker twines have better catch efficiency. The 0.16 mm twine being very thin was easily susceptible to damage when fishes get caught and there could be considerable escape, showing reduction in fish catch.

The total shrimp catch in different modes of operating the cast nets *viz.,* casting the net from shore and from a boat showed no significant difference. This could be due to even distribution of the shrimps in the culture ponds.

6.3.3. Hand picking

The catch ($kg.h^{-1}$) of *P. monodon* and *P. indicus* and other shrimps and total fish caught separately by men and women is given in Table 6.24. *P. indicus* contributed 79.32 %, *P. monodon* 10.28 %, and other shrimps (*M. dobsoni* and *M. monoceros*) 10.40 % of the total shrimp catch. The fish catch mainly comprised of *Etroplus* sp., and *Tilapia* sp. together forming 16.46 % of the total catch.

Table 6.25. gives ANOVA of catch of *P. indicus* handpicked by men and women. There is significant difference between the catch of *P. indicus* ($P<0.001$). Handpicking by women gives significantly higher catch of *P. indicus* than men. Handpicking of shrimps or fish is mostly carried out by the women folk in Kerala and they are more skillful in the work than men.

The shrimp catch depends on the number of shrimp which come into contact with the fishing gear and the number of shrimp captured by the net. This depends on the density of the shrimp, the area of the net, the type of motion of shrimp, its behaviour and position of the net relative to the direction of fish motion. In the case of gill net and cast net, the material and

Table 6.24. Details of catch by handpicking by men and women

Catch	Men	Women	Men	Women	Men	Women
	(kg)		$kg.h^{-1}$		%	
P. monodon	4.3	4.2	0.1	0.1	50.2	49.8
P. indicus	26.7	38.9	0.3	0.5	40.7	59.3
Other shrimps	4.0	4.6	0.0	0.1	46.7	53.3
Total shrimps	35.0	47.7	0.4	0.6	42.3	57.7
Fish	8.2	8.1	0.1	0.1	50.5	49.5
Total catch	**43.17**	**55.75**	**0.54**	**0.69**	**43.6**	**56.4**

Table 6.25. Analysis of variance for men and women and total shrimp catch in hand picking

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.84128	1	0.84128	13.43124	0.0007526	4.09816892
Within Groups	2.380171	38	0.062636			
Total	3.221451	39				
		LSD=	0.110481			

twine thickness plays an important role in the catch efficiency. During this study it was multifilament gill net showed better catch efficiency than monofilament gill nets. It is possible that mechanical factors play a part in this PA multifilament being more softer than the PA monofilament gill nets may not alert the fish much when they touch the net and thus are caught in the net easily. (Baranov, 1976). However, they are not as selective as monofilament gill nets as observed in this study. Mesh selectivity in gill net showed that mesh sizes larger than 34 mm retained more of *P. indicus* of marketable size and therefore these should be used during periodic harvest in the perennial farms. Gill nets of mesh size of 34 mm and above can be used on a regular basis along with the sluice net operations for increasing the catch of larger sized shrimps from the farm.

CHAPTER - 7

MAJOR FACTORS AFFECTING SHRIMP HARVESTING

7. MAJOR FACTORS AFFECTING SHRIMP HARVESTING

7.1. Introduction

The phase of the moon is one of the factors which determines the behaviour of fish (Nomura, 1959, 1961; Hopson, 1962). Variations in the catch due to influence of moon and tide is reported by Isomae (1984), Hickling (1946), Rounsefell and Everhart (1953). Liu (1957) found that the degree of variation in the catch is related to the phase of the moon or to the sequence of the tides. From India, Jayaraman *et al.* (1959), Subramanyam (1965), Bhat *et al.* (1967) and Khagwade (1972) have made brief observations in the variation of trawl catch in relation to the phase of the moon. Mathai *et al.* (1971) and Pati (1981) have made observations on the lunar and tidal influence on gill net catch.

The phase of the moon may exert considerable influence over fishing conditions (Rounsefell and Everhart, 1953; Jayaraman *et al*, 1959; Racek, 1959). This is especially so in the case of crustaceans. A number of marine crustaceans demonstrate specific behaviour in response to environmental stimuli in a wide range of habitats (Lakshmi *et al.*, 1976; Johansson, 1997). Chatterjee *et al.* (1994) and Hamsa (1978), studied the effect of lunar periodicity on the abundance of crabs. The shrimp catch also fluctuate with lunar periodicity (Courtney *et al.*, 1996; Racek, 1959; Ruello, 1975; Griffiths, 1999). The effects of tidal and lunar phases on the penaeid prawn seed abundance were studied by Ganga *et al.* (1990) and Vasudevan and Subramoniam (1985).

The influence of lunar phase on catch and size composition of prawns in stake nets has been studied by (Menon and Raman, 1961; Raman and Menon, 1963; Subramanyam, 1965; Copeland, 1965 George *et al.*, 1995 and Thomas *et al.*, 1999).

Iverson and Idyll (1959) and Ingle *et al.*, (1959) stated that the prawn catch in Tortugas, Florida, is very poor when the moon is full. Racek (1959) while investigating the prawn fisheries of the estuaries and offshore waters in New South Wales distinguished distinct lunar and diurnal abundance in prawn catches and their migrations from inshore to the offshore waters. Griffiths, (1999) studied the effects of lunar periodicity on catches of *P. lebejus* in an Australian coastal lagoon.

Since the extent of relationship between the abundance of fish and the lunar as well as tidal influence has not been fully known, scientific investigations in this direction have been initiated both by Indian and foreign workers in recent years (1934; Liu, 1957, Subramanyam, 1965; Nomura 1959, 1961; Mathai *et al.*,1971; Otubusin, 1990; Beyst *et al.*, 2002).

Catch of adult prawns peaked in the few days leading to full moon in case of commercial fishing methods at sea (Courtney *et al*, 1996). In contrast, Racek (1959) and Ruello (1975) found that catch of sea ward migrating sub adult prawns were highest during the new moon. Influence of tide and lunar periodicity are also seen in the paddy shrimp fishery of Kerala, where the neap tide period is observed to yield such low catches as to render it unremunerative for fishing operation. Consequently this fishery is active during the spring tide period only. As the lunar phase influences catch, fishing is usually carried out around the full moon and the new moon days. In the case of filtration farms the tidal flow of water plays an important factor in the yield of shrimps. Tides are a function of the lunar phase, leading to the greatest sea level fluctuations and the strongest tidal currents at full moon and new moon. The trend of yield from shrimp culture farms in relation to lunar phases has been studied by George *et al.*, (1968).

Fire was used by prehistoric man to attract and catch fish until kerosene and electrical lamps were introduced. It is still used by tribes in remote areas and has lead to the development of fishing with light in recent times (Brandt, 1972). Fire is still being used to attract shrimp juveniles into the filtration farms in Vypeen. The use of light for attracting fish is an important tool in fishing (Ben Yami, 1976). Fish behaviour and reaction to light in general have been studied by several workers (Maeda,1951; Wickham, 1973; Kawamoto,1955 and Tamura,1959). The influence of light of different intensities and colour on fish attraction has been carried out by Borisov (1951), Imamura (1958,1959), Imamura and Koike (1959), Kawamoto (1955, 1959), Kusaka (1965), Yoshimuta and Mitsugi (1963). The reaction of crustaceans to direct and diffused light were reported by Schallck (1943). The catch of penaeid prawns have been shown to vary in response to factors such as light intensity (Wassenberg and Hill, 1994), tidal cycles and salinity (Vance *et al.*, 1994). Kurien *et al.* (1952) carried out studies on the catch of *Penaeus indicus* in Chinese dip nets using different lights.

An attempt is made to study the effects of lunar periods, intensity of light, rate of flow of water and tide on the catch of shrimps harvested from sluice nets and also to study the effect of lunar periodicity on the catch of shrimps from different harvesting techniques in the filtration shrimp culture farms.

7.2. Materials and Methods

7.2.1. Lunar periodicity

The materials for the studies were collected from a 19.2 ha perennial shrimp aquaculture farm at Vypeen island for a period of 18 months from November 1999 to April 2001. The fishing period consisted of 9 fishing days (four days prior to the full moon, full moon day and four days after the full moon day and four days prior to the new moon, new moon day and four days after the new moon day) usually referred as *thakkam*. Random samples from the total catch were taken when the catch obtained was more than 1 kg otherwise, the whole catch was used for analysis. The species composition, species-wise quantity and length frequency of individual shrimp caught were recorded. The total length of individual shrimp was measured to the nearest mm (Sparre *et al.*, 1989). In the case of *Metapenaeus dobsoni* whose length was less than 30 mm the average weight were taken to find out the individual weight of the specimen. Only the total weight of *Penaeus indicus* and *M. dobsoni* has been considered in this study. The data were pooled together for the different phases and the CPUE ($kg.h^{-1}$) calculated for both number and weight. As the prawn filtration practice is mainly dependent on the tidal flow, and influences the catch of shrimps, the average tidal heights for the full moon and new moon periods of fishing was taken (Anon, 1999b, 2000, 2001a) and the corresponding catch were plotted.

The variation in size composition of shrimps with respect to lunar phase as analysed using mean, standard deviation, coefficient of variation and Bowleys coefficient of skewness of the length frequency data. In order to see whether there is any significant difference between the length groups of the selected species and lunar periodicity the data were subjected to chi square (χ^2) tests.

To know the trend of landings of major species of shrimps during the lunar phases from different harvesting techniques, *viz.*, sluice net, gill net and cast net, in the seasonal and perennial farms, the details on the shrimp catch by various gear and efforts expended in hours during the lunar phase were recorded and maintained separately (in a register) in the 6 seasonal and 6 perennial farms selected for the study (Table 2.1. a & b). The species wise catch data in $kg.h^{-1}$ for the different harvesting techniques for perennial farms and seasonal farms were recorded according to lunar phase (*Thakkam)* separately. All the four species *viz., P. monodon, P. indicus, M. dobsoni* and *M. monoceros* were recorded for sluice nets whereas in the case of gill net and cast net only *P. monodon* and *P. indicus* were considered as there was very meagre landings of *M. dobsoni* and *M. monoceros* in these nets. The CPUE ($kg.h^{-1}$) for all the fishing techniques were calculated and two way ANOVA was to find out whether any differences occurred in the shrimp catch with respect to full moon and new moon period during the lunar phase in the seasonal and perennial farms.

7.2.2. Influence of rate of flow of water

Studies on the influence of rate of flow of water on shrimp harvest in sluice gates were conducted during the fishing period (*thakkam*) from February, 2001 to April 2001 from the same farm mentioned above. Readings were taken on the commencement of filtration which was usually just before dusk till the end of the fishing operation. The rate of flow of water out of the farm through the sluice gate was measured using the CIFT water current meter of range 0-400 cm^{-1} sec$\pm$ 1 cm^{-1} (Sivadas, 1987). The instrument was placed at the middle of the sluice gate with its sensor dipped perpendicularly into the flowing water. Ten readings ($cm.sec^{-1}$) from the water current meter were noted every 30 minutes from the commencement of filtration till its completion and the average flow of water calculated. The cod end of the sluice net was also hauled up every 30 minutes just after taking the readings from the flow meter to know the quantity of catch obtained during the observed flow rate.

7.2.3. Influence of temperature and salinity

Surface salinity and temperature of the shrimp culture farm were recorded for three months during the fishing period (*Thakkam)* from February 2001 to April 2001. The salinity and the surface temperature of the farm were recorded every 30 minutes from inside the pond using the CIFT salinity-temperature meter with salinity range between 0-38 ‰ $\pm$ 0.1 ppt and for temperature the range was 15° C to 40° C $\pm$ 1° C (Sivadas, 1978) during the period of operation. The actual salinity values were computed using the temperature correction graph developed by CIFT. The average reading for the day of operation was computed.

7.2.4. Influence of light

The study was conducted from a 77.6 ha perennial shrimp aquaculture farm at Vypeen island which had two sluice gates adjacent to each other. Observations were taken for a period of three months from

February 2001 to April 2001 during (*Thakkam)* for the full moon phase and new moon phase period. As the width of one of the sluice gate was larger by 25 cm, a wooden plank was fixed longitudinally along the side of the larger sluice gate so as to make the width of both the sluice gates equal. The fishing operations were carried out around dusk till late in the night. Kerosene lamps of the same size which were covered in a glass box was used for the experiments. The lamps were placed at the center of the sluice gate just above the water surface at the entrance facing the farm which gave a diffused light near the entrance of the sluice gate. The intensity of light was measured at the entrance of the sluice gate near the surface of the water using a LUX meter of range 0-200 lux, ± 1 lux. For the experiments, one sluice gate was kept as control throughout, where a single kerosene lamp was used regularly during harvesting which is the usual practice followed by the shrimp farmers in the area, and on the adjacent sluice gate the intensity of light was varied by (a) using one kerosene lamp; (b) using two kerosene lamps and (c) without using kerosene lamp. Harvesting was carried out simultaneously from the two sluice gates during all the days of operation of the lunar phase. Random samples were taken from the total catch from each sluice gate and the species composition and species wise quantity were recorded. The CPUE $kg.h^{-1}$ was calculated for each species and also for the total catch.

7.3. Results and Discussion

Fig. 7.1. (a) shows the catch rate ($kg.h^{-1}$) from sluice net and Fig. 7.1 (b & c) shows the catch rate ($kg.h^{-1}$) and $No.h^{-1}$ for *P. indicus* and *M. dobsoni* respectively. The catch rate ($kg.h^{-1}$) during the full moon and two days immediately preceding and succeeding the full moon was 72.7 $kg.h^{-1}$ and during the new moon day and two days immediately preceding and succeeding the new moon was 67.6 $kg.h^{-1}$, whereas during the other days on either side of the full moon and new moon days it was 41.3 $kg.h^{-1}$ and 21.7 $kg.h^{-1}$, respectively. Table 7.1. and Table 7.2. give the number of *P. indicus*

and number of *M. dobsoni* in different length classes from the experimental perennial farm during the full moon and new moon phases.

The mean size of *P. indicus* ranged from 100.5 to 131.8 mm during the full moon period and it ranged from 81.3 to 131.8 mm during the new moon period. Smaller individuals were observed on the second and third day succeeding the new moon day.

Coefficient of variation of the number of *P. indicus* on the full moon day and two days following the new moon day are the highest indicating that variability in catch is more on these days than the rest of the days.

Positive skew for *P. indicus* is seen on the third and fourth day after the full moon day and similarly on the third and fourth day after the new moon day indicating that majority of the shrimps landed during the period are having length more than the modal length during these days of the lunar phase.

In the case of *M. dobsoni,* the mean size ranged from 52.0 to 66.2 mm during the lunar phase. The mean size of *P. dobsoni* ranged from 52.0 to 65.0 during the full moon period and from 52.0 to 66.2 mm during the new moon period indicating better size during the new moon period.

Coefficient of variance of the number of *M. dobsoni* on the day preceding the full moon and two days preceding the new moon day and on the fourth day succeeding the full moon and new moon days are the highest indicating that variability in number of *M.* dobsoni is more on these days than the rest of the other days.

Positive skew for *M. dobsoni* is seen on the second and third day after the full moon day and on the days after the new moon day indicating that majority of the shrimps landed during the period are having length more than the modal length during these days of the lunar phase.

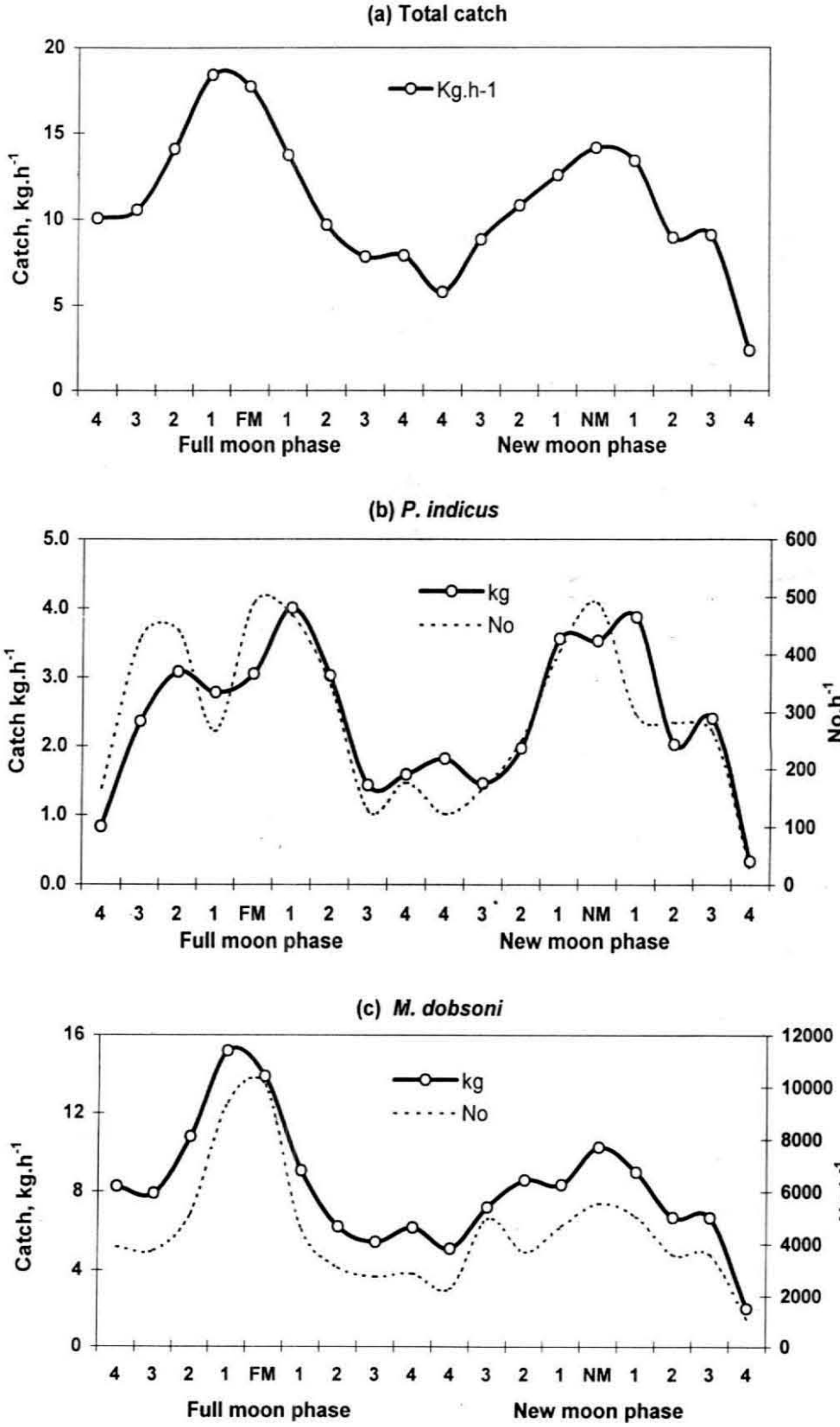


Fig. 7.1. (a, b & c) catch, kg.h^{-1} and numbers.h^{-1} in sluice net from perennial farm

Table 7.1. Number of *P. indicus* in length class from sluice net from a perennial farm during lunar phases.

Length class	*ekadashi*	*daiadashi*	*Thriodashi*	*Chaturdashi*	Full moon	*Prathama*	*Dvithiya*	*Thrithiya*	*Chathurthi*		*ekadashi*	*daiadashi*	*Thriodashi*	*Chaturdashi*	New moon	*Prathama*	*Dvithiya*	*thrithiya*	*chaturthi*
50-60	0	0	0	0	5	2	2	0	0		0	0	0	0	0	0	0	0	0
60-70	4	4	5	0	1	6	0	0	0		0	0	0	6	0	0	0	0	4
70-80	0	4	8	0	52	12	16	0	0		0	0	0	3	6	0	4	4	9
80-90	6	6	9	0	28	11	13	0	0		0	0	0	13	23	0	16	13	11
90-100	5	39	46	7	45	24	37	0	0		0	0	0	10	36	4	20	19	4
100-110	1	29	33	7	24	28	18	1	1		0	0	0	17	22	8	26	13	0
110-120	2	28	40	24	49	74	47	6	4		2	3	2	28	72	38	14	1	0
120-130	7	11	22	68	58	100	95	14	6		21	4	17	15	34	34	21	0	0
130-140	0	2	13	29	19	46	41	9	6		4	3	39	32	4	28	30	0	0
140-150	0	1	15	12	7	14	16	5	0		3	7	31	25	7	23	16	0	0
150-160	0	0	0	3	2	2	16	2	0		0	11	12	9	4	6	1	0	0
160-170	0	0	0	0	0	0	0	0	0		0	5	6	0	1	0	0	0	0
170-180	0	0	0	0	0	1	0	0	0		0	0	0	0	3	0	0	0	0
180-190	0	0	0	0	0	1	0	0	0		0	0	0	0	1	0	0	0	0
Total Nos	**25**	**124**	**191**	**150**	**290**	**323**	**301**	**37**	**17**		**30**	**30**	**30**	**158**	**213**	**141**	**141**	**141**	**28**

Table 7.2. Number of *M. dobsoni* in length class from sluice net in a perennial farm during lunar phases.

Length class	*ekadashi*	*daiadashi*	*Thriodashi*	*Chaturdashi*	Full moon	*Prathama*	*Dvithiya*	*Thrithiya*	*Chathurthi*		*ekadashi*	*daiadashi*	*Thriodashi*	*Chaturdashi*	New moon	*Prathama*	*Dvithiya*	*thrithiya*	*chaturthi*
20-30	0	0	0	16	38	3	3	1	1		0	0	0	0	0	26	28	4	4
30-40	6	9	21	384	197	27	21	5	4		0	20	0	45	16	238	124	20	14
40-50	85	146	295	919	1445	457	373	90	59		53	305	159	696	816	583	520	74	51
50-60	129	208	435	2806	2424	998	866	264	117		169	729	608	1701	1488	1223	789	143	39
60-70	192	348	698	2532	1073	776	700	238	82		256	486	1007	1331	1224	1645	394	69	37
70-80	113	201	406	1567	390	348	299	81	56		172	126	674	419	352	579	445	74	44
80-90	97	159	318	210	370	313	268	81	48		56	55	243	395	536	413	439	66	36
90-100	22	34	69	115	37	195	165	36	32		59	10	253	190	180	88	19	3	2
100-110	0	0	0	0	0	6	6	4	0		0	5	0	8	16	0	0	0	0
Total	**644**	**1105**	**2242**	**8549**	**5974**	**3123**	**2701**	**800**	**399**		**765**	**2342**	**3300**	**4785**	**4628**	**4795**	**4098**	**1368**	**227**

Table. 7.3. gives the χ^2 for *P. indicus* in length class for the days in the lunar phase (significance level varies from 5 % to 0.1 %). During full moon days length class 70-80, 80-90, 90-100, 100-110, 110-120 and 120-130 mm are significantly higher. Maximum number of *P. indicus* was observed on full moon day and two days after the full moon day which belong to length class 70-80, 120-130 mm, respectively. But during new moon days length class 80-90, 90-100 and 110-120 mm are significantly higher. Maximum number is observed in the size range 120-130 during the fishing period.

Table. 7.4. gives the χ^2 for *P. indicus* in length class for the full moon and new moon period (significance level varies from 5 % to 0.1 %). Length class 50-60, 70-80, 90-100, 100110, 110-120, 120-130, 140-150, 150-160, 160-170 mm shows significant difference between full moon and new moon phase. Between full moon and new moon period significantly higher numbers are observed in the length class 120-130 mm. Maximum number of *P. indicus* is observed during the full moon phase.

Table. 7.5. gives the χ^2 for *M. dobsoni* in length class for the days in the lunar phase (significance level varies from 5 % to 0.1 %) During full moon period length class 30-40, 40-50, 50-60, 60-70 and 70-80 mm are significantly higher. Very high catch is observed on one day prior to full moon day which belong to length class 50-60. But during new moon days length class 30-40, 40-50, 50-60, 60-70, 70-80 and 80-90 mm are significantly higher and the highest size range is in the length class 50-60 mm.

Table. 7.6. gives the χ^2 for *M. dobsoni* in length class for the days in the full moon and new moon period (significance level varies from 5 % to 0.1 %). Length class 30-40, 50-60, 60-70, 70-80, 80-90 mm shows significant difference between full moon and new moon phase. Between full moon and new moon period, significantly higher numbers of *M. dobsoni* is observed in the length class 50-60 mm. Among the two phases more number of *M. dobsoni* is observed during the new moon phase.

Table 7.3. Chi square test of *P. indicus* in length class from sluice net in a perennial farm during lunar phases

Length class	*ekadashi*	*daiadashi*	*Thriodahsi*	*Chaturdashi*	**Full moon**	*Prathama*	*Dvithiya*	*Thrithiya*	*Chathurthi*		*ekadashi*	*daiadashi*	*Thriodahsi*	*Chaturdashi*	**New moon**	*Prathama*	*Dvithiya*	*thrithiya*	*chaturthi*	Total
50-60	0.5	0.5	0.5	0.5	40.5	4.5	4.5	0.5	0.5		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	**57.00**
60-70	3.3	3.3	6.7	1.7	0.3	11.3	1.7	1.7	1.7		1.7	1.7	1.7	11.3	1.7	1.7	1.7	1.7	3.3	**57.60**
70-80	6.6	1.0	0.3	6.6	315.0	4.5	13.6	6.6	6.6		6.6	6.6	6.6	1.9	0.0	6.6	1.0	1.0	0.9	**391.80**
80-90	0.6	0.6	0.1	8.3	47.0	0.9	2.7	8.3	8.3		8.3	8.3	8.3	2.7	26.2	8.3	7.2	2.7	0.9	**149.51**
90-100	8.0	30.9	53.1	5.4	49.6	3.5	25.7	16.4	16.4		16.4	16.4	16.4	2.5	23.3	9.4	0.8	0.4	9.4	**304.20**
100-110	10.7	21.1	32.6	2.5	10.1	18.6	2.2	10.7	10.7		12.7	12.7	12.7	1.5	6.9	1.7	14.0	0.0	12.7	**194.21**
110-120	20.3	0.6	10.5	0.0	25.7	103.2	21.7	13.6	16.8		20.3	18.5	20.3	0.6	95.1	8.0	4.2	22.2	24.1	**425.69**
120-130	17.0	11.4	1.8	51.2	28.2	170.8	147.5	8.0	18.5		2.3	21.8	5.1	7.0	0.8	0.8	2.3	29.3	29.3	**553.10**
130-140	16.9	13.2	0.9	8.6	0.2	49.8	34.2	3.7	7.1		9.9	11.5	28.7	13.4	9.9	7.2	10.1	16.9	16.9	**259.14**
140-150	10.1	8.2	2.4	0.4	1.0	1.5	3.4	2.6	10.1		5.0	1.0	43.2	21.9	1.0	16.4	3.4	10.1	10.1	**151.69**
150-160	3.8	3.8	3.8	0.2	0.8	0.8	39.5	0.8	3.8		3.8	13.8	17.9	7.2	0.0	1.3	2.0	3.8	3.8	**110.94**
160-170	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7		0.7	28.2	42.7	0.7	0.2	0.7	0.7	0.7	0.7	**81.00**
170-180	0.2	0.2	0.2	0.2	0.2	2.7	0.2	0.2	0.2		0.2	0.2	0.2	0.2	34.7	0.2	0.2	0.2	0.2	**41.00**
180-190	0.1	0.1	0.1	0.1	0.1	7.1	0.1	0.1	0.1		0.1	0.1	0.1	0.1	7.1	0.1	0.1	0.1	0.1	**16.00**
Total	**86.4**	**0.4**	**26.7**	**2.6**	**190.4**	**278.0**	**217.8**	**68.1**	**99.9**		**78.5**	**78.5**	**78.5**	**5.3**	**50.2**	**0.7**	**0.7**	**0.7**	**81.6**	**1344.91**

Table 7.4. Chi square test of *P. indicus* from sluice net in a perennial farm during full moon and new moon periods

Length class	Total FM Phase	Total NM Phase	Sum of FM & NM	Average		Chi Square FM	Chi Square NM	Sum FM & NM
50-60	9.0	0.0	9.0	4.5		4.500	4.500	**9.000**
60-70	20.0	10.0	30.0	15.0		1.667	1.667	**3.333**
70-80	92.0	26.0	118.0	59.0		18.458	18.458	**36.915**
80-90	73.0	76.0	149.0	74.5		0.030	0.030	**0.060**
90-100	203.0	93.0	296.0	148.0		20.439	20.439	**40.878**
100-110	142.0	86.0	228.0	114.0		6.877	6.877	**13.754**
110-120	274.0	160.0	434.0	217.0		14.972	14.972	**29.945**
120-130	381.0	146.0	527.0	263.5		52.396	52.396	**104.791**
130-140	165.0	140.0	305.0	152.5		1.025	1.025	**2.049**
140-150	70.0	112.0	182.0	91.0		4.846	4.846	**9.692**
150-160	25.0	43.0	68.0	34.0		2.382	2.382	**4.765**
160-170	0.0	12.0	12.0	6.0		6.000	6.000	**12.000**
170-180	1.0	3.0	4.0	2.0		0.500	0.500	**1.000**
180-190	1.0	1.0	2.0	1.0		0.000	0.000	**0.000**
Total	**1458.0**	**912.0**	**2370.0**	**1185.0**		**62.894**	**62.894**	**125.787**

Table 7.5. Chi square test of *M. dobsoni* from sluice net in a perennial farm during lunar phases

Length class	*ekadashi*	*daiadashi*	*Thriodashi*	*Chaturdashi*	**Full moon**	*Prathama*	*Dvithiya*	*Thrithiya*	*Chathurthi*		*ekadashi*	*daiadashi*	*Thriodashi*	*Chaturdashi*	**New moon**	*Prathama*	*Dvithiya*	*thrithiya*	*chaturthi*	Total
20-30	7	7	7	12	141	2	2	5	5		7	7	7	7	7	53	65	1	1	**342**
30-40	53	47	29	1602	277	21	29	54	56		64	30	64	6	36	474	56	30	39	**2967**
40-50	244	158	26	691	2780	9	1	236	287		297	21	142	228	446	88	39	262	300	**6255**
50-60	603	476	196	4592	2980	29	1	396	623		537	15	64	880	498	174	3	579	765	**13412**
60-70	394	198	1	4480	165	3	1	329	572		305	80	108	502	340	1159	153	596	655	**10039**
70-80	163	65	8	4183	4	0	8	209	249		92	146	293	13	0	145	24	220	270	**6094**
80-90	75	21	36	1	89	32	7	95	142		130	131	1	122	416	150	195	115	162	**1920**
90-100	46	30	3	12	26	147	79	27	32		7	65	341	134	110	0	50	78	80	**1268**
100-110	3	3	3	3	3	5	5	1	3		3	3	3	12	73	3	3	3	3	**128**
Total	**144**	**424**	**1745**	**25374**	**12391**	**3386**	**2533**	**222**	**55**		**203**	**1904**	**3781**	**7949**	**7436**	**7983**	**5831**	**650**	**18**	**82029**

Table 7.7. (a, b, & c) gives the species-wise catch rate from two sluice gates with varying number of kerosene lamps. To know if there is any significant difference in the catch among the two sluice gates, with varying number of lamps, analysis of variance was carried out using two way ANOVA. There is no significant difference in total catch between the two sluice gates when only one kerosene lamp was used in each of the sluice gate. Two way ANOVA also did not show any significant difference in total catch between the two sluice gates when one lamp was used in one sluice gate and two lamps were used in the other sluice gate. Table 7.8. shows significant difference ($P < 0.01$) in total catch between the sluice gates with one lamp and without lamp. Sluice gate with one lamp gives significantly higher catch than the sluice gate without lamp.

To find out if there is any significant difference in catch during the new moon and full moon periods separately, further analysis using two way ANOVA was done separately for the two phases. There is no significant difference in the total catch between the two sluice gates with one lamp each during both the full moon and new moon periods. Similarly, there is no significant difference in the total catch between the two sluice gates with one lamp and two lamps respectively during the full moon phase. However, there is significant difference ($P < 0.01$) in the total catch between the two sluice gates during the new moon period. Table 7.9. shows significantly higher catch in sluice gate with two lamps than the catch in sluice gate with one lamp during the new moon period. Table 7.10. gives the ANOVA for one lamp and no lamp during the new moon phase. There is significant difference ($P < 0.01$) in the total catch between the two sluice gates. The sluice gate with one light gives significantly higher catch than the sluice gate without light during the new moon period. On the other hand there is no significant difference in total catch among the two sluice gates with one lamp and without lamp during the full moon period.

Table 7.6. Chi square test of *M. dobsoni* from sluice net in a perennial farm during full moon and new moon periods

Length class	Total FM Phase	Total NM Phase	Sum of FM & NM	Average		Chi Square FM	Chi Square NM	Sum FM & NM
20-30	62	62	124	62		0.00	0.00	**0.00**
30-40	674	477	1151	576		16.86	16.86	**33.72**
40-50	3869	3257	7126	3563		26.28	26.28	**52.56**
50-60	8247	6889	15136	7568		60.92	60.92	**121.84**
60-70	6639	6449	13088	6544		1.38	1.38	**2.76**
70-80	3461	2885	6346	3173		26.14	26.14	**52.28**
80-90	1864	2239	4103	2052		17.14	17.14	**34.27**
90-100	705	804	1509	755		3.25	3.25	**6.50**
100-110	16	29	45	23		1.88	1.88	**3.76**
Total	**25537**	**26308**	**51845**	**25923**		**5.73**	**5.73**	**11.47**

FM = Full moon NM = New moon

Table 7. 7. (a) Species wise catch, kg.h^{-1} with one kerosene lamp

Lunar phase	*Monodon*	*Indicus*	*Dobsoni*	*Monoceros*	Total	*Monodon*	*Indicus*	*Dobsoni*	*Monoceros*	Total
	1 lamp					1 lamp				
Ekadashi	0.00	4.67	19.33	0.67	24.67	0.00	5.33	21.00	1.00	27.33
Daiodashi	0.00	0.67	33.67	0.33	34.67	0.00	1.00	32.67	0.33	34.00
Thriodahsi	0.00	3.00	41.75	1.50	46.25	0.00	2.00	40.00	1.75	43.75
Chaturdashi	0.25	0.75	11.25	0.13	12.38	0.00	0.50	12.00	0.13	12.63
Full moon	0.25	1.50	40.00	0.23	41.98	0.13	1.50	41.75	0.25	43.63
Prathama	0.38	6.00	25.25	0.30	31.93	0.25	6.00	24.00	0.25	30.50
Dvithiya	0.25	2.75	8.75	0.70	12.45	0.50	2.25	10.00	0.75	13.50
Thrithiya	0.00	0.33	22.67	0.07	23.07	0.00	0.67	25.00	0.13	25.80
Chaturthi	0.33	3.00	10.00	0.08	13.42	0.33	2.33	11.67	0.13	14.47
Ekadashi	0.00	1.00	15.00	0.07	16.07	0.00	1.00	13.67	0.11	14.78
Daiodashi	0.00	0.33	15.67	0.08	16.08	0.00	0.33	17.00	0.10	17.43
Thriodahsi	0.00	0.25	12.50	0.06	12.81	0.00	0.25	10.00	0.06	10.31
Chaturdashi	0.25	1.75	14.00	0.90	16.90	0.25	1.25	13.00	1.00	15.50
New moon	0.25	1.50	15.00	0.25	17.00	0.25	1.50	16.25	0.25	18.25
Prathama	0.00	0.25	12.25	0.05	12.55	0.00	0.25	12.00	0.08	12.33
Dvithiya	0.00	1.25	30.00	0.08	31.33	0.25	1.00	30.50	0.06	31.81
Thrithiya	0.00	0.33	26.67	0.08	27.08	0.00	0.33	29.33	0.67	30.33
Chaturthi	0.00	0.33	16.33	0.08	17.33	0.00	0.33	16.67	0.08	17.08

Table 7. 7. (b) Species wise catch, $kg.h^{-1}$ with 1 and 2 kerosene lamps

Lunar phase	*Monodon*	*Indicus*	*Dobsoni*	*Monoceros*	Total	*Monodon*	*Indicus*	*Dobsoni*	*Monoceros*	Total
	1 lamp					2 lamp				
Ekadashi	0.00	0.03	8.33	0.17	8.53	0.00	0.03	9.00	0.08	9.12
Daiodashi	0.00	0.03	17.33	0.07	17.43	0.00	0.07	15.00	0.08	15.15
Thriodahsi	0.25	1.25	11.25	0.50	13.25	0.25	1.00	11.25	0.50	13.00
Chaturdashi	0.25	3.75	8.50	2.00	14.50	0.00	3.75	7.50	2.50	13.75
Full moon	0.40	1.25	40.50	0.13	42.28	0.25	1.75	40.00	0.50	42.50
Prathama	0.25	1.75	10.00	0.05	12.05	0.00	2.00	11.25	0.06	13.31
Dvithiya	0.25	5.00	7.50	0.13	12.88	0.25	5.00	5.00	0.25	10.50
Thrithiya	0.40	2.33	34.00	0.83	37.57	0.00	2.67	32.67	1.00	36.33
Chaturthi	0.00	0.07	4.00	0.03	4.10	0.00	0.08	5.67	0.07	5.82
Ekadashi	0.00	0.04	4.00	0.07	4.11	0.00	0.07	2.67	0.10	2.83
Daiodashi	0.00	1.00	20.00	0.67	21.67	0.00	1.67	25.67	1.33	28.67
Thriodahsi	0.00	0.75	6.25	0.04	7.04	0.00	0.75	10.00	0.50	11.25
Chaturdashi	0.25	0.25	12.50	0.25	13.25	0.00	0.13	13.75	0.13	14.00
New moon	0.00	0.50	25.00	0.75	26.25	0.00	1.00	30.00	1.25	32.25
Prathama	0.00	1.75	5.00	0.03	6.78	0.25	2.00	6.25	0.25	8.75
Dvithiya	0.00	1.75	11.50	0.63	13.88	0.25	2.00	13.50	0.38	16.13
Thrithiya	0.33	0.67	16.67	0.33	18.00	0.33	0.33	23.33	0.10	24.10
Chaturthi	0.00	0.03	6.67	0.03	6.73	0.00	0.08	10.00	0.03	10.11

Table 7. 7. (c) Species wise catch, kg.h^{-1} with 1 and no kerosene lamp

Lunar phase	*Monodon*	*Indicus*	*Dobsoni*	*Monoceros*	Total	*Monodon*	*Indicus*	*Dobsoni*	*Monoceros*	Total
	1 lamp					without lamp				
Ekadashi	0.00	0.10	10.00	0.00	10.10	0.00	0.07	8.33	0.00	8.40
Daiodashi	0.00	4.00	10.00	0.00	14.00	0.00	3.33	13.33	0.00	16.67
Thriodahsi	0.25	0.05	12.50	0.00	12.80	0.25	0.20	12.75	0.00	13.20
Chaturdashi	0.25	1.00	20.00	0.20	21.45	0.25	1.50	17.50	0.25	19.50
Full moon	0.30	6.25	13.75	1.50	21.80	0.25	3.75	11.50	2.00	17.50
Prathama	0.63	3.25	40.00	0.25	44.13	0.25	1.75	45.00	0.25	47.25
Dvithiya	0.38	0.25	2.50	0.50	4.00	0.38	0.25	3.00	0.25	3.50
Thrithiya	0.33	5.00	8.67	0.00	14.00	0.17	3.33	7.00	0.00	10.50
Chaturthi	0.25	1.75	15.75	0.25	18.00	0.13	1.25	14.50	0.50	16.38
Ekadashi	0.00	0.08	6.67	0.00	6.75	0.00	0.07	4.00	0.00	4.07
Daiodashi	0.00	0.10	6.00	0.00	6.10	0.00	0.10	3.33	0.00	3.43
Thriodahsi	0.00	1.25	30.00	0.25	31.50	0.00	1.00	25.75	1.00	27.75
Chaturdashi	0.13	1.00	14.50	0.00	15.63	0.00	0.25	10.00	0.00	10.25
New moon	0.00	2.50	17.50	0.00	20.00	0.00	1.25	12.50	0.00	13.75
Prathama	0.00	1.00	31.25	0.50	32.75	0.00	0.25	19.75	1.00	21.00
Dvithiya	0.25	1.00	7.50	0.00	8.75	0.13	0.50	5.00	0.00	5.63
Thrithiya	0.00	0.03	23.33	0.00	23.37	0.00	0.13	12.67	0.00	12.80
Chaturthi	0.00	0.05	10.67	0.00	10.72	0.00	0.13	9.33	0.00	9.47

Table. 7.8. ANOVA of shrimp catch for one lamp and without lamp during lunar phases

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Days	3609.116	17	212.301	29.11794	2.68E-09	2.271893
Sluice gate (1L & NL)	83.41778	1	83.41778	11.44109	0.00354	4.451323
Error	123.9482	17	7.29107			
Total	3816.482	35				

Table. 7.9. ANOVA of shrimp catch for one lamp and two lamps during new moon period

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Phase	1214.559	8	151.8198	40.55589	1.11E-05	3.438103
Sluice gate (1L & 2L)	51.29438	1	51.29438	13.70236	0.006028	5.317645
Error	29.94777	8	3.743472			
Total	1295.801	17				

Table. 7.10. ANOVA of shrimp catch for one lamp and without lamp during new moon period

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Phase	1305.857	8	163.2321	24.28224	7.78E-05	3.438103
Sluice gate (1L & NL)	124.9078	1	124.9078	18.58116	0.002579	5.317645
Error	53.77825	8	6.722281			
Total	1484.543	17				

Fig. 7.2. shows the average tidal gradient for the fishing season for the period from November 1999 to April 2001 with corresponding average catch. From this it can be presumed that higher catch is seen with the increased tidal gradient which falls mostly during the full moon period.

Fig. 7.3. Shows the trend of catch in relation to rate of flow of water for the fishing period from January 2001 to April 2001.

Temperature and salinity did not vary significantly during the fishing operations. The salinity ranged between 19.3 ‰ and 22.7 ‰ and the temperature ranged between 31.2° C and 32.7° C. When the day to day fluctuations of catch of different species of shrimps and total catch are examined in relation to salinity and temperature, no significant correlation is evident. Similar results were also reported by George *et al.* (1968).

Fig. 7.4. Shows the trend of catch in relation to time for the fishing period from January, 2001 to April, 2001.

Table. 7.11. & Table. 7.12. gives the catch $kg.h^{-1}$ of major species of shrimps landed during the full moon and new moon phases in different harvesting systems from seasonal and perennial farms respectively. The trend of yield in relation to '*thakkam*' in the different harvesting systems from seasonal and perennial farms is shown in Fig. 7.5. (a & b) respectively.

The figure indicates that the catch is invariably higher at the full moon and new moon periods in both the seasonal and perennial farms in all gears.

The data were analysed for any significant difference in catch between the full moon and new moon phase of the moon. Catch $kg.h^{-1}$ during the two phase of the moon analysed using ANOVA showed no significant difference between the two phase for any of the species caught in sluice net in the seasonal and perennial farms respectively.

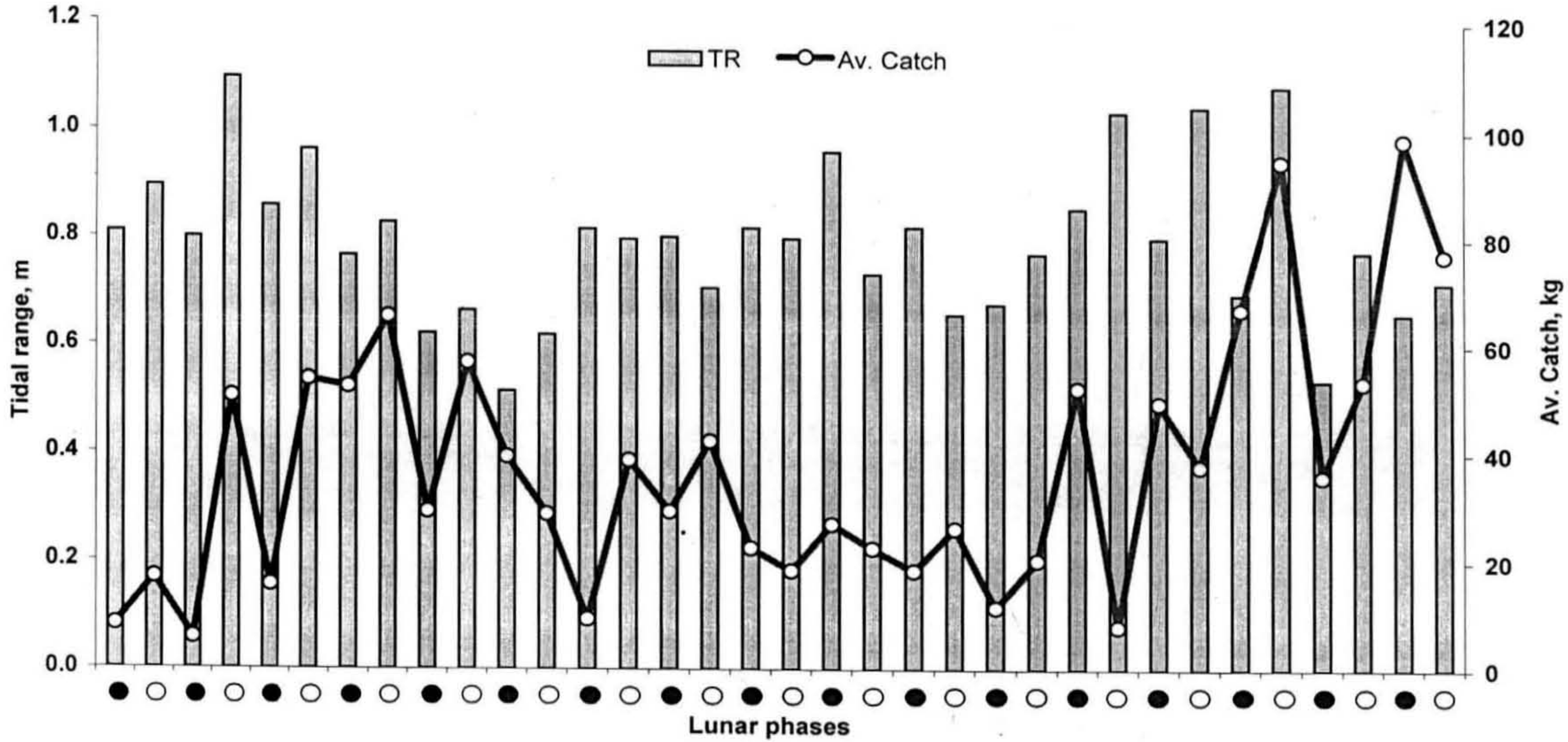


Fig. 7.2. Fortnightly catch with phase of moon and tidal range during the fishing period from November 1999 to April 2001

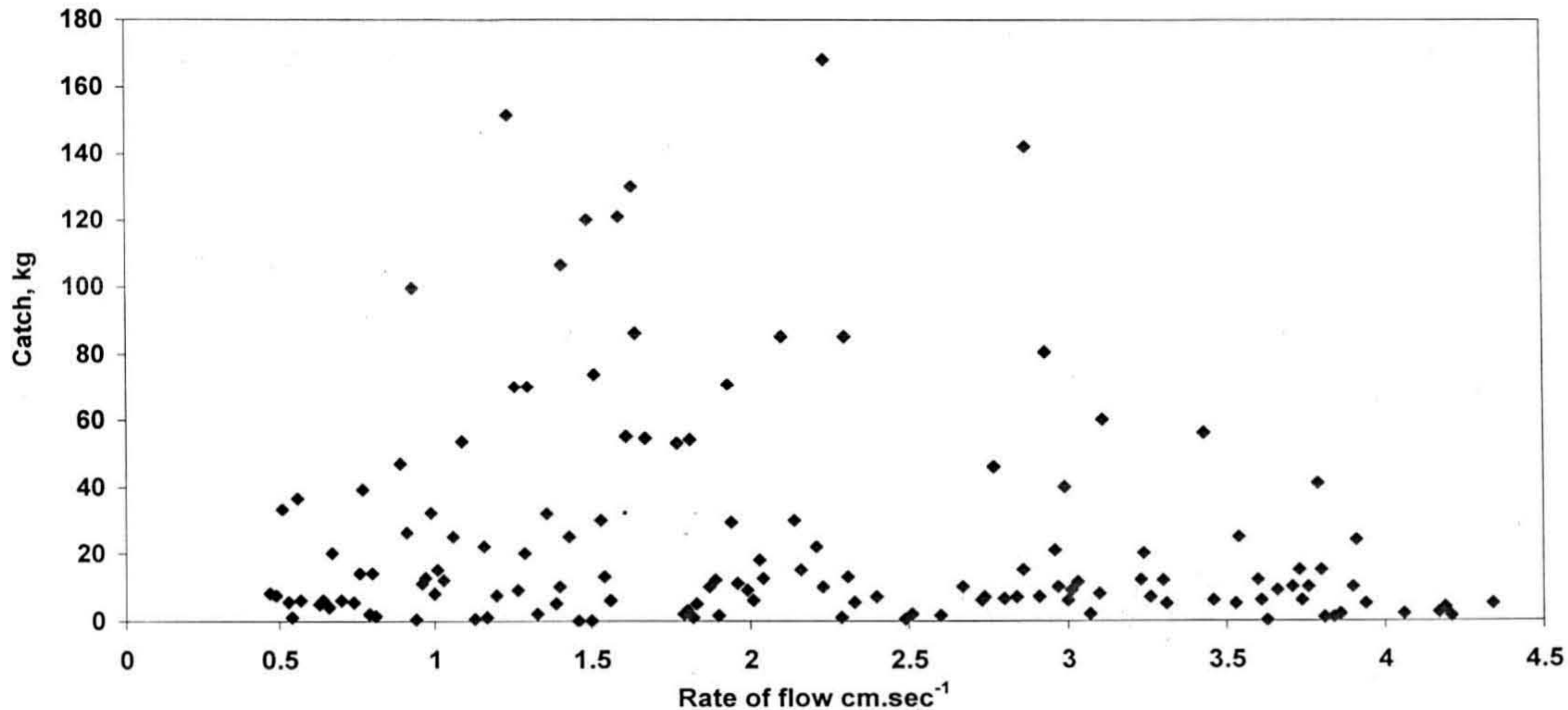


Fig. 7.3. Catch trend in relation to rate of flow of water for the fishing period from January 2001 to April 2001

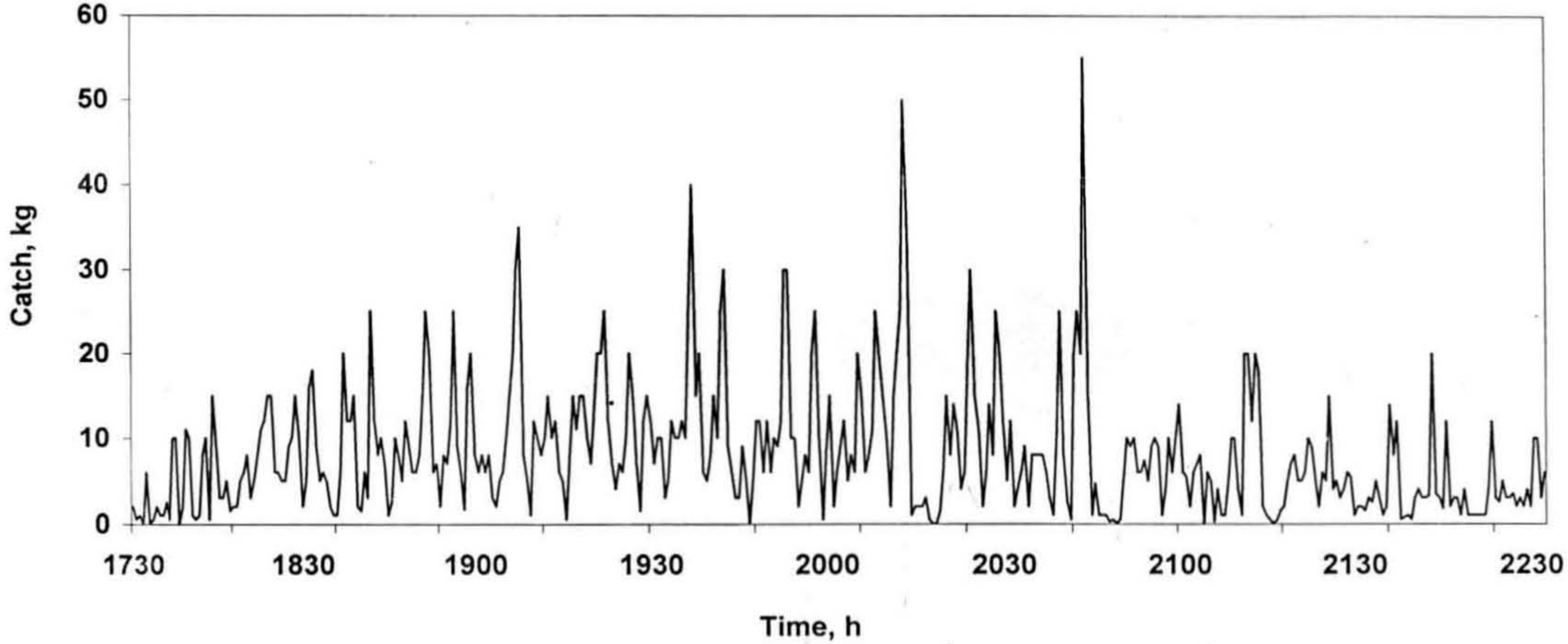
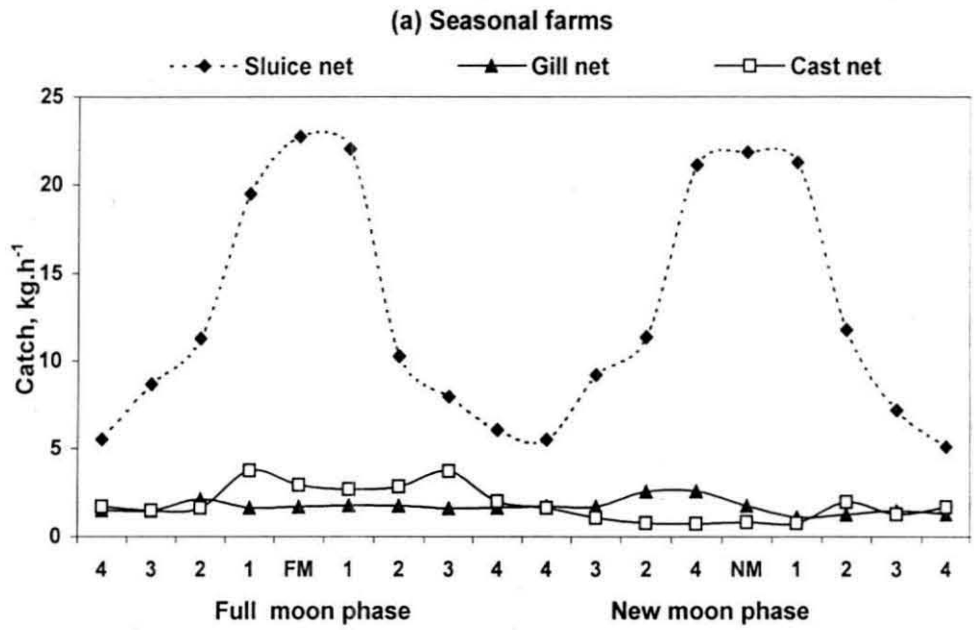


Fig. 7.4. Catch trend in relation to time for the fishing period from January 2001 to April 2001



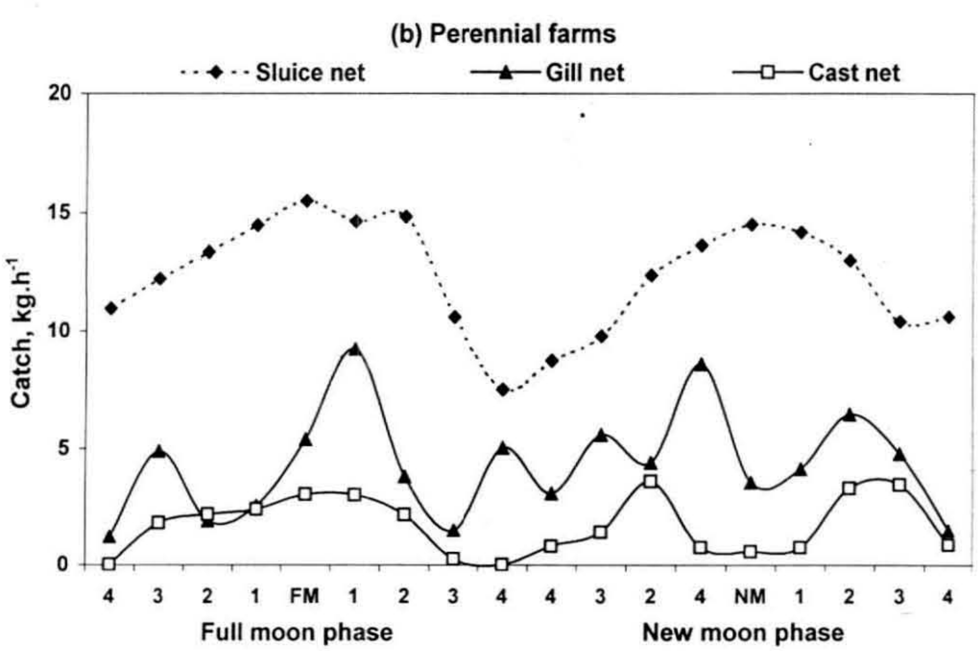


Fig. 7.5. (a & b) catch, $kg.h^{-1}$ from different harvesting systems

Table 7.11. Catch, kg h^{-1} of major species of shrimps during lunar phases in different harvesting systems from perennial farms

Moon phase	Sluice net ($kg.h^{-1}$)				Cast net ($kg.h^{-1}$)		Gill net ($kg.h^{-1}$)	
	P. monodon	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P. monodon*	*P. indicus*	*P. monodon*	*P. indicus*
Ekadashi	0.04	1.82	8.65	0.44	-	-	0.2	1.0
Daiodashi	0.10	2.42	9.42	0.28	1.42	0.39	1.4	3.5
Thriodahsi	0.12	2.00	10.77	0.45	2.54	0.51	0.8	1.1
Chaturdashi	0.16	2.56	11.33	0.41	3.11	0.42	1.2	1.4
Full moon	0.27	2.52	12.20	0.50	4.06	0.87	0.8	4.6
Prathama	0.23	3.38	10.54	0.48	2.18	2.03	2.1	7.1
Dvithiya	0.15	3.35	10.81	0.51	1.32	1.66	3.2	0.7
Thrithiya	0.16	2.00	8.19	0.25	0.56	0.12	0.8	0.7
Chaturthi	0.08	1.29	5.96	0.18	-	-	1.0	4.0
Ekadashi	0.09	1.65	6.64	0.34	0.94	0.71	1.3	1.8
Daiodashi	0.10	1.51	7.85	0.33	1.21	1.06	0.2	5.3
Thriodahsi	0.14	2.40	9.39	0.44	2.56	2.07	1.1	3.3
Chaturdashi	0.21	2.84	10.07	0.50	1.20	0.56	1.0	7.6
New moon	0.17	3.13	10.70	0.50	0.89	0.44	0.1	3.4
Prathama	0.11	3.28	10.25	0.52	2.20	0.53	0.8	3.3
Dvithiya	0.11	2.66	9.91	0.31	0.14	3.25	3.1	3.3
Thrithiya	0.08	2.20	7.94	0.19	0.51	3.21	1.9	2.8
Chaturthi	0.05	1.83	8.55	0.19	0.16	0.82	0.8	0.7

Table 7.12. Catch, kg h^{-1} of major species of shrimps during lunar phases in different harvesting systems from seasonal farms

Moon phase	Sluice net ($kg.h^{-1}$)				Cast net ($kg.h^{-1}$)		Gill net ($kg.h^{-1}$)	
	P. monodon	*P. indicus*	*M. dobsoni*	*M. monoceros*	*P. monodon*	*P. indicus*	*P. monodon*	*P. indicus*
Ekadashi	0.28	0.34	5.84	0.88	0.48	1.19	0.9	0.6
Daiodashi	0.26	0.91	9.58	0.82	0.43	1.00	0.9	0.6
Thriodahsi	0.60	2.02	11.40	0.99	0.40	1.20	0.9	1.2
Chaturdashi	1.80	5.77	14.80	0.79	1.04	2.67	0.5	1.1
Full moon	1.73	9.47	14.95	0.90	0.25	2.50	0.4	1.2
Prathama	2.10	9.25	14.16	0.68	0.13	2.50	0.8	1.0
Dvithiya	1.54	4.88	9.01	0.19	0.30	2.50	0.6	1.1
Thrithiya	1.40	6.53	3.93	0.25	0.50	3.13	0.3	1.3
Chaturthi	1.26	4.34	2.97	0.63	1.33	0.58	0.5	1.2
Ekadashi	0.23	0.59	5.38	1.11	1.13	0.44	0.7	1.0
Daiodashi	0.27	0.90	9.93	1.15	0.60	0.45	0.8	0.9
Thriodahsi	0.63	1.81	11.41	1.25	0.40	0.35	0.3	2.2
Chaturdashi	1.59	6.02	13.28	1.09	0.25	0.45	1.0	1.6
New moon	1.51	7.72	10.55	0.68	0.50	0.30	1.2	0.5
Prathama	2.43	7.78	11.18	0.73	0.25	0.50	0.7	0.4
Dvithiya	1.14	6.64	7.58	0.29	1.40	0.50	0.9	0.3
Thrithiya	1.27	5.24	4.14	0.26	0.25	1.00	1.2	0.2
Chaturthi	1.21	2.72	3.33	0.47	0.70	0.90	1.0	0.3

Table 7.13. gives two way ANOVA for sluice net in perennial farms and shows significant difference ($P < 0.01$) between days of the lunar phase and catch of different species of shrimp. There is no significant difference in catch on full moon day, and two days succeeding the full moon day and two days preceding the new moon day. Similarly there is no significant difference in catch two days preceding full moon day and on the new moon day. There is significant difference between catch of different species. Maximum catch was obtained for *M. dobsoni* on full moon day and new moon day and for *P. indicus* on the day succeeding the full moon day and new moon day.

Two way ANOVA for analysis of cast net in perennial farms showed no significant difference between days of the lunar phase and catch of different species of shrimp and no significant difference between catch of species.

Table 7.14. gives two way ANOVA for gill net in perennial farms and shows significant difference ($P < 0.01$) between catch of different species of shrimp and days in lunar phase.

Table 7.15. gives two way ANOVA for sluice net in seasonal farms and shows significant difference ($P < 0.01$) between days of the lunar phase and catch of different species of shrimp. There is no significant difference in catch on new moon day, and two days preceding the new moon day and on the full moon day and one day succeeding the full moon day. Maximum catch was obtained for *M. dobsoni* on full moon day and one day preceding the new moon day and for *P. indicus* on the full moon day and one day succeeding the new moon day.

Two way ANOVA for cast net in seasonal farms showed no significant difference between days of the lunar phase and catch of different species of shrimp and no significant difference between catch of species.

Table. 7.13. Analysis of variance in sluice net of perennial farms

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Days	5.718965	17	0.33641	5.835135	4.45E-07	1.827146
Shrimp	202.749	3	67.583	1172.249	5.2E-47	2.78623
Error	2.940274	51	0.057652			
Total	211.4082	71				
		Days		LSD =	0.15687076	
		Shrimp		LSD =	0.33277314	

Table. 7.14. Analysis of variance in gill net of perennial farms

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Days	11.47867	17	0.675216	0.95044	0.54112	2.271893
Shrimp	8.033216	1	8.033216	11.30762	0.003694	4.451323
Error	12.07722	17	0.710425			
Total	31.58911	35				

Table. 7.15. Analysis of variance in sluice net of seasonal farms

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Days	22.49371	17	1.32316	2.832338	0.00211	1.827146
Shrimp	72.90196	3	24.30065	52.01767	1.54E-15	2.78623
Error	23.82524	51	0.467162			
Total	119.2209	71				
		Days		LSD =	0.14121101	
		Shrimp		LSD =	0.94727228	

Two way ANOVA for gill net in seasonal farms showed no significant difference between days of the lunar phase and catch of different species of shrimp and no significant difference between catch of species.

From the present study it is apparent that there is significant relationship between shrimp catch and the lunar periods, tidal rhythms, rate of flow of water and light. The prawn catch was high in and around the full moon and new moon days. Smaller mean size of *P. indicus* was observed during the darker phase of the moon and the variability in catch by number was more on the full moon day and also on two days after the new moon day. Majority of them were having length more than the modal length during the days after the full moon day and new moon day. Maximum number of *P. indicus* in the length class 120-130 mm was observed during full moon period and in the length class 110-120 and 120-130 during the new moon period indicating active movement of large size shrimps towards the sea during the full moon and new moon days.

In the case of *M. dobsoni* larger size range was observed during the darker phase of the moon. This is contradictory to the observations made by George *et al.* (1998) and Thomas, *et al.* (1999) who suggested smaller sizes of *M. dobsoni* preferred darker nights and there was less variability in the number of shrimps on the full moon day and new moon days. Majority of them were having length more than the modal length during the days immediately after the full moon day and after the new moon day. Maximum number of *M. dobsoni* of the length class 50-60 mm was seen during the new moon and full moon period.

Menon and Raman (1961), pointed out the stronger tidal currents prevailing on these days (full moon or new moon days or on either of the other 2 days) and the more active movement of shrimps on lunar phase as the possible reasons for the higher catch on these days. Raman and Menon (1963) and George *et al.* (1968) also made similar observations of catch during the lunar phases. Copeland (1965) also observed that the catch was more on new moon and full moon days than at the quarters. The present observations also showed similar results.

The reports by different workers are varied. Menon and Raman (1961) did not notice any significant difference in catch between darker and brighter nights. George *et al.* (1998) observed new moon period influencing the catch of *P. indicus* only. Subramanyam (1965) observed higher catch on new moon. Thomas *et al.* (1999) observed no significant difference between the new moon and full moon phase. The reasons may be due to the tidal action rather than the light intensity of the moon influencing the shrimp catch. Liu (1957) suggested that the strength of the tidal flow could be the probable reason for the fluctuations in the catch.

Subramanyam (1965) observed relatively better catch of shrimps during the darker fortnights in the stake net fishery of Godavari estuarine system on the east coast of India. Racek (1959) noticed that the school of king prawn catch fluctuates within a lunar month being greatest shortly before new moon and smallest 3-4 days before full moon. Ingle *et al.* (1959) and Iverson and Idyll (1959) observed that the prawn catch in Tortugas, Florida are poor when the moon is full.

The results on the rate of flow of water in harvesting shrimps from the sluice net showed that when the rate of flow of water was very high (> 3.0 cm.sec^{-1}) the catch was comparatively less. High catch observed during the full moon and new moon days could be due to longer duration of fishing which occurs during the high tide and the amount of water to be filtered out of the farm. However, when the time of fishing and catch was observed, It becomes evident that the catch is more dependent on time rather than the rate of flow of water. Though fishing operations commenced on some days at 17:00 h, and showed higher rate of flow of water, maximum catch was observed only after dusk with no relation to the rate of flow of water. However, the catch was less as the time progressed with reduction in the rate of flow of water. This could be due to the fact that shrimp become more active during night. Wassenberg and Hill (1994) found that *P. plebejus* emerges from being buried in the substrate only when light intensity decreases.

Laboratory experiments have shown the influence of light which on the behaviour of shrimps (Racek, 1959). The phase of the moon influences the height of the tide which directly influences the tidal flow from the filtration farms.

The present study indicates that artificial light could influence the catch of shrimp harvesting. The experiments have shown that the catches in sluice gate are significantly higher when provided with lamps, during the new moon phase, indicating light as one of the important factors influencing the catch of shrimps. The efficiency of any light fishing system may be greatest during periods of new moon (Verheyen, 1959; Wickham, 1970), before midnight (Tamura, 1959; Wickham, 1970) and just before dawn (Wickham, 1970). as the farm under study being very large, it is possible that the shrimps at the farther end of the farm may not be attracted to the light placed at the sluice gate. It appears that the shrimps are influenced more by the tidal flow and move towards the exit, as they approach the exit, they are attracted towards the light and are moved towards the sluice net.

There are many factors which influence the catch of shrimp from the culture farms . The major factors being the phase of the moon, light, tide, and rate of flow of water. Though there was fluctuation of catch in the different species of shrimp, it was observed that generally the shrimp catch was more during the new moon and full moon periods. Light placed at the sluice gate plays an important role to attract shrimps towards the sluice gate, use of more light did not show any considerable increase in catch. The high tide increases the filtration rate and the duration of filtration of water from the farm. The increase of rate of flow of water did not show any corresponding increase of shrimp catch. It is evident from the results that time of operation during the lunar phase is crucial for attracting more shrimps towards the sluice gate. Shrimps were observed to aggregate towards the sluice gate during dusk and break of dawn and the catch was invariably higher consequent to this period. The longer duration of water flow from the shrimp farm to the backwater also increased the shrimp catch in the sluice net. However, no one factor could be attributed for the increase in shrimp catch. It appears that all the major factors have a combined influence on the shrimp catch.

CHAPTER -8

ECONOMICS OF TRADITIONAL SHRIMP FARMING AND HARVESTING

8. ECONOMICS OF TRADITIONAL SHRIMP FARMING AND HARVESTING

8.1. Introduction

Aquaculture has been receiving much importance during the last few decades due to the tremendous potential it has in augmenting shrimp production and increasing employment opportunities in the rural sector. Shrimp production through aquaculture reached about 82,634 t during 1989-99 (Anon, 2001b). The traditional paddy field prawn culture in Kerala has been practised in an organized manner in the tide affected fields adjoining open backwater systems in central Kerala. Studies on yield and economics of this system are very few. The production level of a prawn field depends upon many factors such as its geographical position, nearness to open backwater system, inherent productivity, the nature of traversing canals and the possibility for adequate prawn fry recruitment and optimum stocking of shrimp seeds. The previous year's performance of the field in terms of yield is also given due importance. On the contrary for the paddy fields that are located far interior from the main backwater systems, the lease amount is low due to its low production.

Economics of various brackishwater shrimp farming systems have been reported by Greenfield (1975), George (1978), Gopalan *et al.* (1978), Mammen *et al.* (1979), Hirasawa and Walford (1979) Srivastava *et al.* (1983), Griffin *et al.* (1985), Ayappa, (1985), Hirasawa (1985), Israel *et al.* 1985), and Fast *et al.* (1990), Cha *et al.* (1997). Marketing aspects of shrimps were studied by Rajendran (1980), Devarajan (1983), Rao *et al.* (1986) Jayaraman (1987), Houston and Nieto (1988) and Chidambaran & Rajan (1990). Studies on the economics of aquaculture systems in India have been carried out by Singh & Pandey (1968). Jayarajan *et al.* (1987) on the economic analysis of prawn culture in Andhra Pradesh, Rani *et. al.* (1993), on the economics of brackishwater prawn farming in Nellore district of

Andhra Pradesh and Reddi (1980), on the economics of shrimp farming in Karnataka are other notable studies. Most of these studies were dealing with scientific shrimp culture in an intensive scale.

Mode of operation and yield obtained through the traditional shrimp culture systems have been reported by Menon, (1954), Gopinath (1956), George (1974), Gopalan *et al.* (1982), Purushan (1987) and Unnithan (2000). Studies on the yield and economics of the traditional shrimp culture practice is recent and very few Pai *et al.* (1982), Jose *et al.* (1987), George (1974, 1978); Gopalan *et al.* (1978), Gopalan *et al.* (1982), Gopalan and Purushan, (1981), Raje and Radade (1980), Purushan (1987), Sathiadhas *et al.* (1989) and Mathew (1993). An area extending upto 12511 ha of low lying coastal region in Kerala is utilized for paddy–cum shrimp culture Anon (1991). In the study area of Vypeen, shrimp filtration is mostly carried out by contractors who take the farms on lease. In the contract system the highest bidder gets the shrimp farm on lease for the a period of 6 months in the case of seasonal farms and for a period of 12 months in perennial farms. The lease amount varies according to the location and proximity to the bar mouth as this has impact on the productivity of the field.

The ultimate credit worthiness of a technology is assessed on the basis of economic performance of the technology. A fishing technology especially the traditional technology can survive because of its place in the traditional life of the fishermen. Such survival of technology as a way of life can continue only in a static and quarantined environment where change from outside hardly influences business outlook of fishermen. Modern fisheries are subjected to intense influences from sources ranging from everyday media to professional extension agencies. Change has become the rule rather than an exception in the dynamic world of production and marketing. Fisheries have become monitized, commercialized and globalised during the past two decades. It is the profitability that is the primary criterion of choice of technology in fisheries.

Traditional shrimp farming in Vypeen falls into two distinct business practices, (a) seasonal and (b) perennial shrimp culture. Logic of this classification has already been dealt in Chapter 1. The normal business practice is to obtain the farm on lease by open auction. However, there are cases where the owners of relatively small farms do the shrimp culture practice by themselves.

This chapter deals with economics of seasonal and perennial farms in Vypeen island with emphasis on harvesting aspects.

8.2. Materials and Methods

The seasonal and perennial farms selected for the other studies as detailed in Table 2.1. were considered for the economic analysis. In the case of seasonal farms, two fishing seasons from November 1999 to April 2000 and November 2000 to April 2001 and in the case of perennial farms, one full season from November 1999 to October 2000 has been taken for the analysis. Data on different cost items and returns were collected during the study period at micro level from each farm with the help of a pre-tested proforma. The investment details were collected only during the initial stage before the commencement of the actual shrimp culture operations and other factors included operational costs, catch composition, quantity and revenue. Cost items were surveyed from the farms every fortnight during the lunar phase (*Thakkam)* and recorded item wise cost as and when these were incurred. Data on return was also recorded by periodic observation by making visits during sluice net operation in the lunar phase. Details of periodic harvest using gill nets, cast nets and handpicking in case of perennial farms and final harvest using the same fishing techniques in case of seasonal farms were also collected separately coinciding with the harvesting time. The average was taken for the seasonal and perennial farms and finally the respective values per hectare was calculated. The economic efficiency was analysed using return on investment. Input-output ratio was estimated using the formula.

$$\text{Input-output ratio} = \frac{\text{Gross returns}}{\text{Total costs}}$$

8.3. Results and Discussion

The total cost of shrimp farming can be divided into two categories. The division follows the standard classification of cost – fixed costs and variable costs apportioned to one crop and is given in Table. 8.1. (Cost structure). The total cost of production per ha was higher in seasonal farms (Rs. 61,620) than in perennial farms (Rs. 52,109). The fixed costs constitute the major cost item in shrimp farming. The fixed costs takes a considerable share in total cost of production. It accounts for 60.9 % of total cost where as variable cost is only 39.1 % of the total cost for perennial farms. The same trend is observed in seasonal farms too, where fixed costs, accounts for 61.7 % of total cost and variable cost accounts for 38.3 %. The material cost was 14.6 % and 21.3 % of the total cost for the perennial and seasonal farms respectively. The labour cost accounts for 21.1 % of the total cost in perennial farms and 14.9 % of the total cost in seasonal farms.

8.3.1. Fixed costs

The principal and perhaps the only fixed cost item in the traditional shrimp farming is the cost of lease value of the farm. In the case of perennial farms the lease value is levied for one year where as in the case of seasonal farms the lease value is for six month period. Average of the lease value of two classes of farms are worked out and presented in Table. 8.1. (Under fixed costs). Fixed cost includes interest cost on the lease value of the farm at the rate of 12 %. The fixed costs works out to 0.32 lakhs per ha for perennial farms and Rs. 0.38 lakh per ha in the case of seasonal farm. It is clearly observed that the lease value per ha is considerably higher for seasonal farms than for perennial farms. The seasonal farms are relatively smaller than the perennial farms and therefore managed more efficiently

Table 8.1. Cost structure per ha (Rs.) of perennial and seasonal farms

Type of farm	Fixed costs (Rs.)			Variable cost (Rs.)				Tota cost
	Lease amount	Annual interest	Total	Material cost	Labour cost	Others	Total	
Perennial farms	28,771	3,452	32,223	7,723	11,155	1,801	20,679	52,902
Seasonal farms	33,922	4,071	37,993	13,096	9,187	1,345	23,628	61,621

attending to the farming practices more effectively whereas the perennial farms stretch thinly the managerial factor because of their large size. The required managerial control and practice is less effective leading to lower productivity. Consequently, bidders for larger farms offer lower lease amount than that offered to the smaller seasonal farms.

The operation of diminishing marginal return is very acute in the case of shrimp farming. This is because of the fact that every individual activity from farm preparation to seeding, feeding and harvesting is very sensitive activity, the perfection and promptness of which can have serious impact on the survival and growth of shrimps. The larger the farm the lesser will be the promptitude of action leading to lesser productivity. The difference in fixed costs of two classes of farms are attributed to these factors.

8.3.2. Variable costs

The breakdown of variable cost into its different components are presented in Table 8.1. The two principal component of variable costs are labour and material. Fig. 8.1. gives the percentage composition of operational cost per ha in perennial farms. It can be seen that the harvesting cost is the highest (32 %) of the total operation cost followed by labour (22 %) , cost of seed and feed (19 %) material cost (19 %) and other costs (18 %) . Fig. 8.2. gives the percentage composition of operational cost per ha in seasonal farms. Here the highest cost component is the cost of seed and feed followed by labour, material cost, harvesting and other costs. Variable cost as such is higher in seasonal farms compared to perennial farms. The cost per ha is, thus higher in the case of seasonal farms. Higher cost is, however, attributable to more intense cultivation practices. It is seen that seasonal farms use more material than perennial farms. This is an indication of some degree of intensive practice in seasonal farm. Investigation reveals that seasonal farms incur comparatively more monetary cost on feed material , seed material etc. In contrast, perennial farms largely follow the factors of natural stocking of shrimp seeds and natural feeds. These differing practices lead to difference in cost.

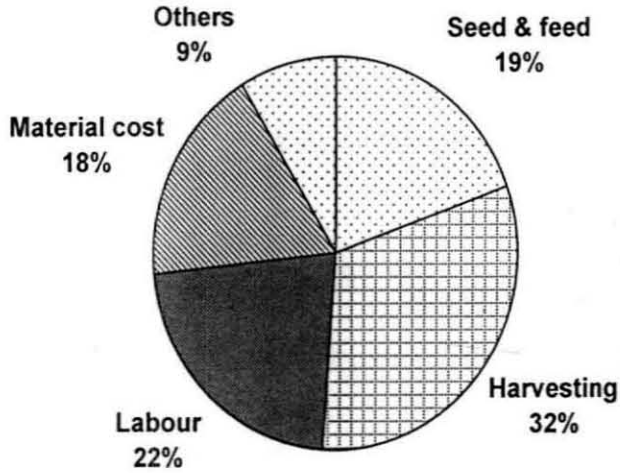


Fig. 8.1. Operational cost in perennial farms

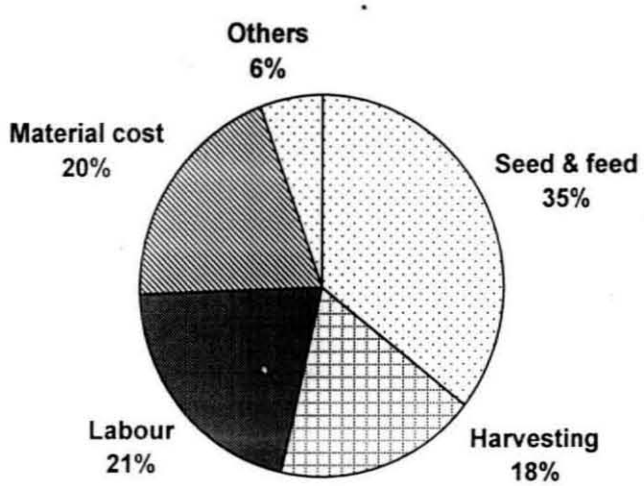


Fig. 8.2. Operational cost in seasonal farms

There is a marginal increase in labour costs in perennial farms as compared to seasonal farms. The difference is not considered to be substantial to make any reliable inference. However, the perennial farms have a tendency to employ more labour on account of their practice of periodical harvesting especially quarterly operation using gears other than the filtration net.

Deducting from the operational profit, the annual fixed cost per ha of Rs. 32,223/- in perennial farms, we get a business or disposable income of Rs. 10,117/- was obtained. Treating this as the annual yield on investment of Rs. 32,223/- the rate of profit works out to 31.4%. The amount required to run the farm is as high as Rs. 20,679/- (variable cost).

In the case of seasonal farms while deducting from the operational profit, the annual fixed cost per ha of Rs 37,993/- a business or disposable income of Rs. 15,757/- was obtained . Treating this as the annual yield on investment of Rs. 37,993/- the rate of profit works out to 41.5%. The amount required to run the farm is as high as Rs. 23,628/- (variable cost). The variable cost cannot be treated as an investment because variable cost is not incurred at one point of time. It is spent over the whole period of operation. Further, accrual of income is also periodic. Harvest and sales takes place continuously at least every fortnight (*Thakkam*). The proceeds can be utilized to keep the farm in operation. Therefore it is justified to calculate the rate of return on the fixed cost only.

Both classes of farms face factors that lead to spiraling costs and unreliability of revenue. On the cost side, the lease amount keeps on increasing year after year. For instance the current lease amount is higher by 21 % for seasonal farms and 20 % for perennial seasonal farms as compared to previous year.

8.3.3. Returns

The average market rates for different species of shrimps and fish were taken for calculation of the sale proceeds. The yield obtained per crop per ha are presented in Table 8.2. The returns from shrimp farming depends on the (a) market rates of different species of shrimps and fish and (b) yield of different species of shrimps and fish. The average yield is 273 $kg.ha^{-1}yr^{-1}$ in perennial farms and 410 $kg.ha^{-1} yr^{-1}$ in seasonal farms. We note that the difference in yield per ha is substantial between the two classes of farms. The yield difference between the two farms taking the perennial farm as the base, works out to 50.2 %. This enormous difference in per ha yield corroborates the operation of law of diminishing returns in perennial farms.

George (1974) recorded average annual shrimp production of 903.3 $kg.ha^{-1}$ and 838.6 $kg.ha^{-1}$ for seasonal and perennial fields respectively. Where as Pillai & Krishnan (1998) recorded an average annual shrimp production of 353.8 $kg.ha^{-1}$and 209.5 $kg.ha^{-1}$ respectively from seasonal and perennial farms of Kerala. Menon (1954) has arrived at an overall average annual yield of 1079 $kg.ha^{-1}$. George *et al.* (1968) have reported a yield of 514 $kg.ha^{-1}$ in Kerala from seasonal farms. A traditionally operated seasonal field at Vypeen island in Kerala yielded 637 $kg.ha^{-1}$ (Gopalan *et al.*, 1982). The average shrimp yield in seasonal farms was as high as 1079 $kg.ha^{-1}$ (Menon, 1954) and 1184 $kg.ha^{-1}$ (Gopinath, 1956). It was around 1400 $kg.ha^{-1}$ in 1940s, 1200 $kg.ha^{-1}$ in 1950s, and 600-800 $kg.ha^{-1}$ in 1970s (Gopalan & Purushan, 1981). It has further come down to merely 353.8 $kg.ha^{-1}$ in 1996 (Pillai & Krishnan, 1998).

Table 8.3. shows the returns per ha from perennial and seasonal farms. The returns from the perennial farms fetch a gross return of 63,018 $Rs.ha^{-1}$ Deducting from this, the entire variable cost of Rs. 20,679/- we get an operational profit of 42,340 $Rs.ha^{-1}$ is obtained. In the seasonal farms, the returns fetch a gross of 77,378 $Rs.ha^{-1}$ Deducting from this, the entire variable cost of Rs. 23,628/- an operational profit of 53,750 $Rs.ha^{-1}$ is obtained. This is the amount that accrue as surplus in the process of carrying out farming. The input-output ratio of perennial farms is 1.20 and that of seasonal farm is 1.30. This means that for every rupee invested on shrimp production, the additional returns realized were 0.20 on perennial farm and

Table 8.2. Yeild and returns per ha (Rs.) from different harvesting techniques from perennial and seasonal farms

Type of Farm	Quantity (kg)				Revenue (Rs.)				Periodicity of revenue yield			
	Sluice net	Gill net	Cast net	Hand picking	Sluice net	Gill net	Cast net	Hand picking	Sluice net	Gill net	Cast net	Hand picking
Perennial farms	189	42	28	14	35,199	13,800	9,410	4,609	every fortnight for one year	4 times in a year		once a year
Seasonal farms	371	15	6	18	67,542	3,864	972	5,000	every fortnight for 5 months	once in the culminating month of culture peirod		

Table 8.3. Returns per ha (Rs.) from perennial and seasonal farms

Type of farm	Gross return	Net return	Repayment of loan	Disposable income
Perennial farms	63,018	42,340	32,223	10,117
Seasonal farms	77,378	53,750	37,993	15,757

0.30 on seasonal farms. The seasonal farm which use commercial feed is a victim of ever increasing feed prices. Labour cost is also subject to periodic rise. On the revenue side, shrimp farm faces a fluctuating trend in shrimp prices, depending upon vagaries of export market. The drop in the price in shrimp during the latter part of the study period has burdened the traditional shrimp farmer. In addition to this, the outbreak of disease has also cut into the profit margin of the traditional shrimp farmer.

In general, the seasonal and perennial shrimp culture farms in Kerala show a gradual decline in the yield. In the present study the average yield from seasonal farm was 410 $kg.ha^{-1}$ and from perennial farm the average yield was only 273 $kg.ha^{-1}$. This shows a regressive trend in the shrimp productivity of these fields. The reasons could be due to over exploitation of natural seeds from the backwaters and inshore areas during the last two decades mainly by the stake nets and other gears which use very small mesh size entrapping the juveniles. This could have an adverse impact on the flow of juvenile shrimps from the sea into the shrimp filtration farms. While evaluating the merits and demerits and ecological and techno-economic aspects of the traditional practices, Muthu (1978a) has highlighted the scope for improving the culture practices and production trend by way of propagating the selective farming of shrimps at semi intensive and intensive levels. Commercially important species of shrimps like *P. monodon* and *P. indicus* are stocked due to their fast growth, large size and high economic value (Alagarswami, 1990). The retarding trend of quality shrimp production from paddy fields has resulted in stocking of selected commercial species of shrimp seeds (Purushan and Rajendran, 1984; Purushan, 1987; Pillai & Krishnan, 1998). Exclusively stocking of seeds of commercial species of shrimps like *P. indicus* and *P. monodon* proportionate to the area and productivity of fields and growing them for definite periods to achieve better productivity and higher profits has been proposed by Unnithan (1985, 1996).

8.3.4. Harvesting aspects

Shrimps are mostly caught by way of filtration through sluice gates during favourable tides of the full moon and new moon phase. Several other harvesting methods such as gill nets, cast nets, drag nets, scoop nets and handpicking are also employed during terminal lease period of the shrimp farm. Harvesting is a labour intensive component especially in the case of perennial shrimp farms. The farm owners employ labour for harvesting mainly through the two trade unions *viz.,* CITU and AITUC at Vypeen. The wages of the harvesting labour is fixed by the respective unions. An average amount of Rs. 63/- for one kg of shrimp caught along with Rs. 15/- for tea and snacks is provided to a labour irrespective of the fishing gear and method. The gill nets and cast nets are usually given first priority and these gear are used periodically once in three months. Only during the last phase of the lease period, handpicking is carried out to harvest the remaining shrimps. As the rate fixed is per kg of shrimp, the fishermen tend to use gill nets and cast nets with smaller mesh size to get more quantity by weight of shrimp and fish. This adversely affects the returns to the farm owner due to large number of small size shrimp in the total catch which would fetch him lesser price. Efficient techniques like electric harvesting for the shrimps from the culture farms will have to be seriously looked into. The pros and cons of this technique will have to be viewed before introducing them into the harvesting regime. Though this may enormously benefit the shrimp farm owner, there could be socio-economic repercussions due to the problem of unemployment.

Experiments with selectivity and efficiency showed that mesh sizes larger than 34 mm can be used in the initial harvesting stages, allowing the smaller shrimps to grow in the pond and attain the commercial size to make profit. During the terminal period, harvesting of shrimps can be done using nets with different mesh sizes to harvest all the shrimps irrespective of its size before the lease period is completed. Multifilament material can be preferred as its catch efficiency is higher than that of monofilament gill nets

(6^{th} Chapter). Usually, the fish caught in the net is given to the fisherman himself. The fish is auctioned only if large quantities are caught.

The split up of the harvesting costs for seasonal and perennial farms is given in Table 8.4.The harvesting cost per ha in perennial farms is highest for gill nets (Rs. 2,331/-) followed by sluice net (Rs. 1,797/-), cast net (Rs. 1458/-) and hand picking (Rs. 979/-). In the case of seasonal farms, the major chunk of the harvesting cost per ha is attributed to sluice net (Rs. 3388/-) followed hand picking (Rs. 382/-), gill net (Rs. 370/-) and cast net (Rs. 86/-). This difference between the seasonal and perennial farms is mainly due to the fact that the operation of gill nets, cast nets and handpicking is carried out only during the last phase of the culture period in case of seasonal farms where as these fishing methods are used periodically at least once in three months in the case of perennial farms.

When the yields and returns from the different harvesting systems in perennial farms are examined, it can be seen that sluice net contributed the maximum yield 69.3 % of the total catch but the returns was only 55.9 % (Fig. 8.3.). Higher yield are seen in case of sluice net mainly due to its continuous operation and also due high percentage of *M. dobsoni* (43 %) and *M. monoceros* (2.9 %) in the total sluice net catch. As this operation is very frequent and continuous during the lunar phase (*Thakkam*), it is observed that more smaller size shrimps are seen in this type of harvesting, It is observed that the yield from gill net was 15.3 % of the total catch but the returns from gill net was 21.9 %. The yield from cast nets was 10.4 % and the returns 14.9 %, from handpicking the yield was only 5 % and the returns 7.3 %. This increase in the returns in the gill nets, cast nets and handpicking fishing techniques is mainly due to landing of larger species of shrimps like *P. Monodon* and *P. indicus* which costs more than *M. dobsoni*. However, the returns from sluice nets was 55.9 %, which was more than returns from other nets.

In the case of seasonal farms, it can be seen that maximum yield was from the sluice net contributing 90.4 % of the total catch and

Table 8.4. Harvesting cost per ha (Rs.) for different harvesting techniques in perennial and seasonal farms

Farms	Sluice	Gill	Cast	Hand	Total
Perennial	2,31,000	3,03,474	1,89,861	1,27,510	**8,54,845**
Harvesting cost per ha	1,797	2,331	1,458	979	**6,566**
Percentage	27.4	35.5	22.2	14.9	**100**
Seasonal	3,49,000	3,81,39	8,819	39,311	**4,35,269**
Harvesting cost per ha	3,388	370	86	382	**4,226**
Percentage	80.2	8.8	2.0	9.0	**100**

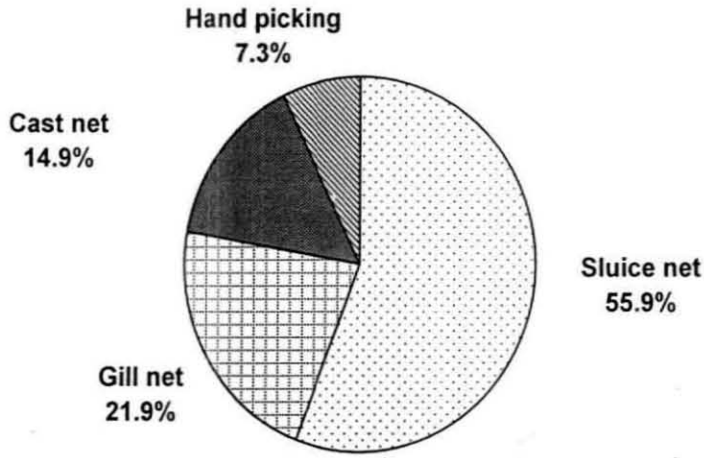


Fig. 8.3. Revenue from different harvesting techniques in perennial farms

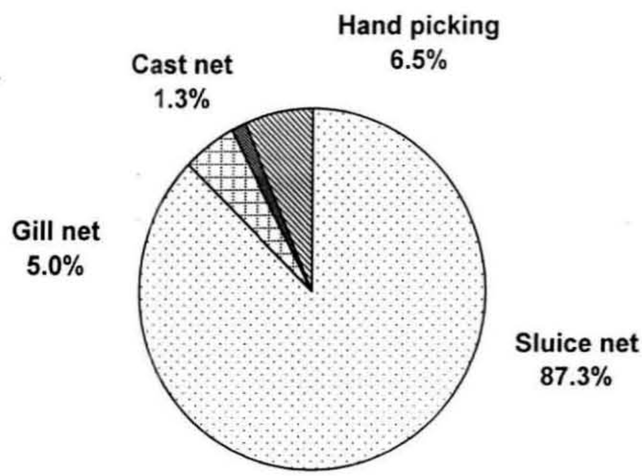


Fig. 8.4. Revenue from different harvesting techniques in seasonal farms

similarly the returns was also high 87.3 % (Fig. 8.4.). Higher yields are seen in case of sluice net mainly due to its continuous operation and also due to high percentage of *M. dobsoni* (52.2 %) and *M. monoceros* (3.5 %) in the total sluice net catch. The yield from gill net was 3.8 % of the total catch but the returns from gill net was 5 %, the yield from cast nets was 1.4 % and returns 1.3 %, from handpicking the yield was only 4.5 % and the returns 6.5 %. As the seasonal farms are comparatively smaller and shallow, most of the shrimp species are influenced by the tidal flow and are caught in the sluice net itself, unlike the perennial farms, which are much larger and deeper and therefore all the shrimps do move towards the sluice net and therefore, harvesting techniques like gill net, cast nets and handpicking will have to be done periodically. However, larger specimens *P. Monodon* and *P. indicus* are caught in gill nets, cast nets and by hand picking in seasonal farms too, as in the case of perennial farms. The difference in size is very evident from the modal length of different species caught from different harvesting techniques. (Chapter 4, Table. 4.5 & Table 4.6.).

It is evident from the observations made above, that sluice net is the most important gear in filtration farms and is the most economical one. All other major harvesting techniques like gill nets, cast nets and hand picking are to be carried out periodically and judiciously and these fishing techniques are complementary to sluice net in order to maximize shrimp harvest for culture farms.

Shrimp farming is undoubtedly an attractive economic enterprise. What is needed is an organizational protection against economic exploitation reflected in rising costs of inputs and fluctuating prices of output. Also measures such as effective disease control, crop insurance, market intelligence and several such macro-economic mechanisms should be devised to insulate the industry from external shocks.

Summary

Summary

Harvesting plays an important role in any aquaculture system. Studies on shrimp harvesting techniques in the traditional sector of shrimp culture is lacking. Problems in harvesting cultured shrimp are often encountered in the ponds which are not fully drainable as the complete retrieval of the stock is not effected. Different methods of harvesting such as sluice net operation, cast netting, gill netting, complete draining of farm and hand picking are employed at different stages. Harvesting is a labour intensive operation in any aquaculture system. The success of shrimp farming to a great extent depends upon the efficiency of harvesting. Efficiency of harvesting techniques depend on the behaviour of shrimps, which are generally active during nights and during the full moon and new moon phases. Other important factors like tide, light intensity and flow rate of water at sluice gate and time of operation also play a major role during harvesting of shrimps from the shrimp farms.

This study focuses on the different harvesting techniques of shrimps in the traditional shrimp filtration farms in Vypeen, Ernakulam District, Kerala. The content of the thesis is organised into 8 Chapters.

Objectives of the study were to (i) document existing shrimp harvesting techniques with technical design specifications in traditional aquaculture systems (ii) study the intensity of operation and productivity of gear systems in traditional shrimp culture systems, (iii) study the comparative efficiency and selectivity of selected harvesting techniques in traditional shrimp culture systems, (iv) find out the effect of lunar phases on the efficiency of shrimp harvesting in aquaculture, (v) study the influence of light intensity and rate of flow of water at sluice gate in harvesting shrimps and (vi) study the economics of traditional shrimp farming and harvesting techniques.

The introductory Chapter gives the background of the topic of study, its relevance and significance, and sets out the objectives of study.

A review of relevant literature on different aspects in shrimp culture together with the factors affecting the harvest of shrimp in culture farms are presented in the second Chapter. Literature on factors like influence of lunar phases, tide, light intensity and rate of flow of water at sluice gate on shrimp harvesting in traditional farms are dealt with.

The third Chapter deals with the materials and methods adopted for the study. Procedures for collection of design and construction and operational details of harvesting systems; determination of total production, intensity of operation of different harvesting systems, gear-wise and species-wise production; catching efficiency of gillnets and cast nets; selectivity of gillnets; factors affecting efficiency of shrimp harvest, and economic analysis of seasonal and perennial farms with special reference to harvesting aspects are summarised in this Chapter and further elaborated in the respective Chapters.

The fourth Chapter deals with the different harvesting techniques in vogue in shrimp culture with special reference to the traditional shrimp farms. The design details of the different harvesting systems and methods of operation are dealt with. Detailed description of the major fishing techniques such as sluice net operation, gill netting, cast netting and hand picking have been given. Though sluice net is the principal gear operated in both the seasonal and perennial farms, other fishing gears and methods such as gill net, cast net and hand picking are also used periodically and during the time of final harvest.

The fifth Chapter deals with the Intensity of operation of different fishing gears and their respective contribution in the shrimp production from both seasonal and perennial farms The length statistics, sex ratio and total weight of different species of shrimps landed by the different harvesting systems have been discussed. Species composition of shrimps landed in different fishing gears have also been examined.

The catching efficiency of gill nets and cast nets and selectivity of gill nets is dealt in the sixth Chapter. Results relating to optimum selection length, selection factor and optimum mesh size in gill nets for *Penaeus indicus* has been worked out. Relative efficiency with regard to mesh size, twine size and material for gill nets and cast nets has also been discussed. In the case of gill net and cast net, the material and twine thickness plays an important role in the catching efficiency. Multifilament gill net showed better catching efficiency than monofilament gill nets. Mesh selectivity in gill net showed that mesh sizes larger than 34 mm retained more of *P. indicus* of marketable size. Gill nets of mesh size of 34 mm and above can be used on a regular basis along with the sluice net operations for increasing the catch of large sized shrimps from the farm.

The seventh Chapter deals with the important factors influencing efficiency of shrimp harvest in traditional aquaculture. Influence of factors such as lunar phases, tide, flow rate of water and light intensity at sluice gate, on the efficiency of shrimp harvest have been studied in detail. Shrimp catch during the new moon and full moon phase, during tides and at different rates of flow of water have been discussed. The shrimp catch was more during the new moon and full moon periods. Light plays an important role by attracting shrimps towards the sluice gate and can enhance the total catch in the case of sluice net operations. Increased filtration rate due to high tides are also very favourable for the sluice net operations. Operation of sluice net just after dusk showed higher catch during the period of study.

Economic analysis of seasonal and perennial farms with special emphasis on the harvesting aspects is discussed in the eighth Chapter. It is evident from the observations made that, though sluice net is the most important gear in shrimp farms and is the most economical one, all other major harvesting techniques like gill nets, cast nets and hand picking will have to be carried out periodically and judiciously, as these fishing techniques are complementary to sluice net in enhancing the total catch of shrimps from the culture farm.

Recommendations:

1. Polyamide multifilament gill net showed better catch efficiency than polyamide monofilament gill nets. Therefore it is recommended to operate multifilament gill nets in the shrimp farms for harvesting shrimps in preference to monofilament gill nets.

2. As mesh sizes larger than 34 mm retained more of *Penaeus indicus* of marketable size, it is recommended that gill nets with this mesh size specification should be deployed during periodic harvest especially in the perennial farms.

3. Polyamide monofilament netting of twine size 0.20 mm and multifilament netting of twine size 210x1x2 with mesh size 24-28 mm is recommended for construction of cast nets to be deployed in shrimp farms as it gave significantly higher total catch and catch of *P. indicus* than nettings of other specifications.

4. Women folk involved in harvesting operations in shrimp farms have been observed to be more skilful in hand picking of shrimps, than men. In view of this, it is recommended to promote their employment in this particular form of harvesting, for their economic well being and empowerment and in order to maximise the retrieval of cultured shrimps from the farms.

5. Harvesting techniques employing electric trigger mechanism, in order to bring out shrimps buried in mud, holds potential for development, as traditional methods such as sluice net, gill net, cast net and hand picking techniques. are not 100% efficient in retrieval of cultured shrimps from the shrimp farm.

Anon, 1999b. Indian Tide Tables, Indian and selected foreign ports. Surveyor General of India, Dehradun, pp. 93

Anon, 2000. Indian Tide Tables, Indian and selected foreign ports. Surveyor General of India, Dehradun, pp. 91-93

Anon, 2001a. Indian Tide Tables, Indian and selected foreign ports. Surveyor General of India, Dehradun, pp. 91.

Anon, 2001b. An overview of the present state of shrimp aquaculture in India. *Fishing Chimes.* 20(10&11): 11-16.

Anon, 2002. Marine products export review - 1999-2000. MPEDA, Panampilly Nagar, Cochin, pp.156.

Ayappa, N., 1985. A study on economic analysis of shrimp culture MSc. (Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore, pp. 125-126.

Bal, D. V. and Banerji, S. K., 1951. A Survey of the Sea Fisheries in India, *In:* Proc. IPFC. (Third Meeting), Sec II, pp. 176-181.

Baranov, F. I., 1914. The capture of fish by gill nets. Matter. *Poznaniver. Russ. Ryboly.* 3 (6): 56-99.

Baranov, F. I., 1948. Theory and assessment of fishing gear. Pishchepromizdat (Ch. 7. Theory of fishing with gill nets. Transl. From Russian by Ont. Dep. Lands For Malpe Ont.), 45 p.

Baranov, F. I., 1976. Theory of gill net fishing. Selected work on Fishing gear, Vol 1. Commercial Fishing Gear Techniques, Israel Progr. Sci. Trasl. Keter Publishers, Jerusalem, pp. 251-289.

Ben Yami, M., 1976. Fishing with light. Publ, Fishing News (Books) Ltd., Surrey, England. 118 p.

Beyst, B., Vanaverbeke, J., Vincx, M and Mees, J., 2002. Tidal and diurnal periodicity in macrocrustaceans and demersal fish of an exposed sandy beach, with special emphasis on juvenile plaice *Pleuronectes platessa,Mar. Ecol. Prog. Ser.* 225: 263-374.

Bhat, Y. M., Kutty, M. N., Venkatasubbarao, K. and Punwani, D. M., 1967. Ghol Dhara fishery off Bedi port in the Gulf of Kutch. *Indian J. Fish.* 11(1): 135.

Borisov, P. G., 1951. Sostoyanie I perspektivy lova kaspiiskoi lil'ki na elekticheskii svet (The present situation and the prospects of Caspian sprat fishing with electric light). *Rybn. Khoz.*, 27(11): 9-19.

Brandt, A. V., 1972. Fish catching methods of the world. Fishing News (Books) Ltd., London, pp. 240.

Cardover, R., 1987. Prawn farming the Australian way (Pond design, harvesting). Australia *Aquacult. Mag.*, (2)2: 4-6.

Carrothers, P. J. G., 1962. Results of Laboratory and field evaluation of continues filament Isotactic polypropylene fibre for salmon gill nets. Fish. Res. Board Can. Circular, 66 p.

Carter, C. L. B. and West, K., 1964. Use of ' Ulstrow' polypropylene in fishing. *In:* Modern fishing gear of the world 2. Fishing News (Books) Ltd., London, pp. 57-63.

Cha, M. W., Young, L. and Wong K. M., 1997. The fate of traditional extensive (*gei wai*) shrimp farming at the Mai Po Marshes Nature Reserve, Hong Kong. *Hydrobiologia,* 152: 294-303.

Chandramohan, K., Benakappa, S. and Anjanayyappa, H. N., 1999. Pokkali fisheries of Kerala, bane or boon? *Seafood Export Journal,* 39(3): 13 - 15.

Chatterji, A., Ansari, Z. A., Ingole, B. S., Sreepada, R. A., Kanti, A. and Parulekar, A. H., 1994. Effect of lunar periodicity on the abundance of crabs from the Goa coast. *Ind. J. Mar. Sci.*, 23(3): 180-181.

Chidambaran, K. and Rajan. S., 1990. Marine fish marketing in Thiruchandur area in Tamil Nadu. *Fishing Chimes,* 10(9): 82.

Chien, Y. H. and Liao, I. C. 1988. The evolution of prawn grow out systems and their management in Taiwan. Presented at Aquaculture Engineering Technologies for the Future. Univ. Sterling, Scotland, 39 pp.

Clark, J. R., 1960. Report on Selectivity Fishing Gear, ICNAF. Sp. Publ., 2: 27-36.

Collins, J. W., 1882. Gill nets in the Cod fishery: A Description of the Norwegian Cod nets with directions for their use, and a history of their introduction into the United States. *Bull. U. S. Fish Comm.* 1: 1-17.

Copeland, B. J., 1965. Fauna of Aransas Pass Inet, Texas Part 1. Emigration as shown by tide trap collections. *Publ. Inst. Mar. Sci. Univ. Tex.*, 10,1: 9-21.

Courtney, A. J., Die, D. J. and McGilvray, J. G., 1996. Lunar periodicity in catch rate and reproductive condition of adult eastern king prawns, *Penaeus plebejus,* in coastal waters of south-eastern Queensland, *Australia. Mar. Freshwater Res.*, 47: 67-76.

Crosnier, A., 1965. Les Crevettes penaeides du plateau continental malgache. Cah,ORSTM (Ser. Oceanogr,) Suppl. Au, .3(3): 158 p.

De la Cruz, C. R., 1983. Fish Pond Engineering A technical manual for small and medium scale coastal fish farms in Southeast Asia. South China Sea Fisheries Devel. Prog., FAO/ UN Manila, Philippines, SCS Manual No. 5, 180 pp.

Delmendo, M. N. and Rabanal, H. R., 1995. Cultivation of 'Sugpo' jumbo tiger shrimp *P. monodon*; Fabricius with notes on its culture in brackishwater ponds. *In:* IPFC. 6th Sess., 5, 12 p

Devarajan, S., 1983. An economic analysis of prawn fisheries in Tamil Nadu. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, pp. 214-215.

FAO, 1975. FAO Catalogue of small scale fishing gear. Publ. Fishing News (Books) Ltd., Surrey England, 191 p.

Fast, A. W., 1991. Pond harvesting techniques. Marine shrimp culture: Principles and practices. (ed. Fast, A. W., and Lester, L. J.), pp. 399-414.

Fast, A. W., Shang, Y. C., Roger, G. L. and Liao, I. C., 1989. Description of Taiwan intensive shrimp culture farms and simulated transfer to Hawaii. Univ. Hawaii Sea Grant College Prog. Univ Seagrant MR 89, 02. 94 pp.

Fast, A. W., Shang, Y. C., Liao, I. C. and Rogers, G. L., 1990. Comparative economics of Taiwan style intensive shrimp culture in Taiwan and Hawaii. *J. Aquatrop.,* 5(1): 91-101.

Faulkner, G., 1998. Shrimp farmers seine ponds. Fish Farm News., 6.

Fernandez, I., Oliva, M. and Oliva, J., 1996. Utilization of sampling methodology to predict the shrimps moulting. *Rev. Invest. Mar.,*17: 2-3.

Firth, P. E., 1950. Nylon Gill Netting Proves Successful, *Atlantic Fishermen*, 31(10): 16-20.

Fridman, A. L., 1973. Theory and practice of commercial fishing gear, Israel Programe for Scientific Translations Ltd., Jerusalem, 489 pp.

Ganga, V., Neelakantan, K., Neelakantan, B., 1990. Tidal and lunar influences on penaeid prawn seed abundance in the Kali Estuary, Karwar. *Mahasagar.*, 23,(1), 63-69.

Garcia, S and Lhomme, F., 1977. La crevette rose, Penaeus duoraarum notialis de la cote quest Africaine : Evolution des potentialities de capture, FAO Circ. Peches (703), 28 pp.

George, K. V., 1974. Some aspects of prawn culture in the seasonal and perennial fields of Vypeen island. *Indian J. Fish.*, 21(1):1-9.

George, K. V., 1978. Economics of traditional prawn culture practices in Kerala with a note on the advantages of intensive prawn culture. *In:* Proc. First National Symposium on Shrimp Farming. Bombay, 16 – 18 August 1978: 131-137.

George, M. J., 1962. Observations on the size groups of *Penaeus indicus* (Milne Edwards) in the commercial catches of different nets from the backwaters of Cochin . *Indian J. Fish.*, 9(2): 462-475.

George, M. J., Mohamed, K. H, and Pillai, N. N., 1968. Observations on the paddy fields prawn filtration of Kerala, India, FAO, Fish Rep. 57: 427-442.

George, M. J. and Suseelan, C., 1980. Changing pattern of prawn production in small scale fisheries of India. *In:* Proc. IPFC.,19 (3): 402-425.

George, N. A. and Mathai, T. J., 1972. A note on the comparative catch efficiency of nylon and cotton gill nets. *Fish. Technol.*, 9: 81-82.

George, V. C., Gopalan Nayar, S. and Krishna Iyer, H., 1974. Mesh regulation in back water prawn fishing gear. *Fish. Technol.*, 11(2): 117-128.

George, V. C. and Brandt, A. V., 1975. Gill nets, *In* C. Nedelec (Ed.) FAO Catalogue of small scale fishing gear. Fishing News Books Ltd., England. 126 p.

George, V. C., 1991. Studies on Prawn gillnet of Kerala Coast. Ph.D. Thesis, Cochin University of Science and Technology, Cochin, 189 pp.

George, V. C., Vijayan, V., George Mathai, P., Varghese, M. D. and Krishna Iyer, H., 1998. Influence of lunar periodicity on the size composition and abundance of penaeid prawns in stake nets. *Fish. Technol.* 35(2): 67-72.

Ghosh, A., Bhowmik, M. L., Chattopadhyay, G. N. and Chakraborty, R. K., 1985. Package of practices for increasing production in brackishwater fish and shrimp culture. Acuacult. Ext. Man. Cent. Inland fish. Res. Inst., Barrackpore, New Ser. CIFRI, No. 7, 26 pp.

Giesel, P., 1953. Three years experience with Platil nets in Lake-Laach. *Der. Fischwirt.* 3(9): 310-313.

Gopalan, U. K., Purushan, K. S. and Rao. T. S. S., 1978. Case studies on the economics of an improved method of paddy field shrimp culture in Vypeen island, Kerala. *In:* First National Symposium on Shrimp Farming. Bombay, 16 – 18 August 1978, pp. 175-186.

Gopalan, U. K. and Purushan, K. S., 1981. Present status of back water shrimp culture in India. *Sea Food Export Journal*, 8(1): 9-14

Gopalan, U. K., Purushan, K. S., Santhakumari, V. and Kunjamma, P. P. M., 1982. Experimental studies on high density, short-term farming of shrimp *Penaeus indicus* in a "Pokkali" field in Vypeen Island, Kerala. *In:* Proc. of The Symposium on Coastal Aquaculture, Held at Cochin from January 12 to 18, 1980. Part-1: Prawn Culture. Marine Biological Assoc. of India, Cochin India 1982, 6: 151-159.

Gopinath, K., 1953. Some interesting methods of fishing in the backwaters of Travancore. *J. Bombay Nat. Hist. Soc.*, 51: 466-471.

Gopinath, K. 1956. Prawn culture in the rice fields of Travancore-Cochin, India. *In:* Proc. IPFC., 6 (3): 419-424.

Greenfield, J. E., 1975. The economics of shrimp production and marketing. *In:* Proc. 27th Ann. Sess. Gulf Inst & 17th Ann. International Game fish Research Conference, pp. 129-137.

Griffin, W. L., Lawrence, A. L. and Johns, M., 1985. Economics of penaeid culture in Americas. *In*: Proc. First Internet. Conf. Culture of penaeid prawns/shrimps (ed. Taki, Y., Primavera, J. H. and Lilbrera, J. H.) 4-7 Dec. 1984. Iloilo city, Philippines, Aquaculture. Dept. SEAFDEC, pp. 151-160.

Griffiths, S. P., 1999. Effects of lunar periodicity on catches of *Penaeus plebejus* (Hess) in an Australian coastal lagoon. *Fish. Research,* 42: 195-199.

Gudger, E. W., 1952. Fishing with hand in certain Asiatic countries. *J. Zool. Soc. India.,* 3: 357-363.

Gulland, J. A., 1983. Fish Stock Assessment. A Manual of Basic Methods. FAO/Wiley Series on Food Agriculture, Vol. 1 FAO, Rome, 223 pp.

Hamley, J. M. and Regier, H. A., 1973. Direct Estimates of Gill Net Selectivity to Walleye (Stizostedion vitreum vitreum). *J. Fish. Res. Board Can.*, 30: 817-830.

Hamley, J. M., 1975. Review of Gill Net Selectivity, *J. Fish. Res. Board Can.,* 32(11): 1943-1969.

Hamsa, K. M. S. A., 1978. On the meat content of *Portunus pelagicus* with some observations on lunar periodicity in relation to abundance, weight and moulting. *Indian J. Fish.*, 25 (1-2): 165-170.

Havinga, B. and Deedler, C. L., 1949. The relation between the size of meshes of gill nets and the size of *Luciperca Sandra* in the Catches, Rapp. P. – V. Reun. Con. Int. Explor. Mer., 125: 59-62.

Hickling, C.F., 1946. The herring fisheries at Milford Haven, *Journ Mar. Biol. , Asso.* UK: 26(3).

Hirasawa, Y. and Walford, J., 1979. The economics of Kuruma ebi (*Penaeus japonicus*) shrimp farming. *In*: Advances in Aquaculture (ed. Pillai, T. V. R.), Fishing News (Books) Ltd., England, pp. 288-298.

Hirasawa, Y. 1985. Economics of shrimp culture in Asia. *In:* Proc. First International Conference on the culture of Penaeid prawns/shrimps. (ed. Taki, Y., Primavera, J. H. and Lilbrera, J. H.). Southeast Asian Fisheries Devel. Centre, Iloilo, Philippines, pp.131-150.

Hodgson, W. C., 1927. Preliminary note on experiments concerning the selective action of drift nets. *J. Cons. Cons Int. Explor. Mer,* 2: 356-360.

Hodgson, W. C., 1933. Further experiments on the selective action of commercial drift nets. *J. Cons. Cons Int. Explor. Mer*, 8: 344-354.

Holt, S. J., 1963. A Method of Determining Gear Selectivity and its Application, ICNAF Spec. pub., 5: 106-115.

Honda, K. and Osada, S., 1964. Polypropylene twines in Japan, *In:* Modern Fishing Gear of the World, Vol.2 Kristjonsson, H. (Ed.)., Fishing News (Books) Ltd., London, pp. 55-57.

Hornell, J., 1925. The fishing methods of Madras Presidency. Part I. The Coromandol coast . *Madras Fisheries Bulletin.,* 18 (2): 59-110.

Hornell, J., 1938. The fishing methods of Madras Presidency. Part II. The Malabar coast. *Madras Fisheries Bulletin.*, 27 (1): 69 p.

Houston, J. E. and Nieto, A., 1988. Impact of regional shrimp production. Consumer income and inputs on excess prices. *Res. Bull. Georgia Agric. Exp. Sta.,* 377: 25.

Hussenot, J., Faivre, C., Hatt, P. J., Blachier, P. and Guillaut, M., 1991. An autonomous electric trawl to determine the biomass of a shrimp pond of *P. japonicus. Aquaculture and the environment.,* 14: 157-158.

Imamura, Y., 1958. Study on the disposition of fish towards light, 2. The strength of illumination preferred by fish. *J. Tokyo Univ. Fish.,* 44(1-2): 89.

Imamura, Y., 1959. Study on the disposition of fish towards light, 4. The strength of illumination comfortable to mackerel and *Trachurus japonicus* . *J. Tokyo Univ. Fish.,* 45(2): 185-93.

Imamura, Y. and Koike, A., 1959. Study on the disposition of fish towards light, 3. The strength of illumination comfortable to *Cololabis saira. J. Tokyo Univ. Fish.*, 45(2): 179-83.

Ingle, R. M., Bonnie Eldred., Jones, H. and Hutton. R. F., 1959. Fla. State Bd. Conserv. Tech. Ser., 32: 1-45.

Israel, D. F., Apud, F. D. and Franco, N., 1985. The economics of different prawn and shrimp pond culture systems : a comparative analysis. *In:* Proc. 1st Internat. Conf. culture of penaeid prawns/shrimps, (ed. Taki, Y., Primavera, J. H. and Lilbrera, J. H.), 4 – 7 Dec, 1984, Iloilo city, Philippines. Aquacult. Dept. SEAFDEC, Abst., pp. 172-173

Iverson, E. S. and Idyll. C. P., 1959. Fla. State Bd. Conserv. Tech. Ser., 29: 1-35.

James, A. W. and James, N. S., 1993. Intensive shrimp production in round ponds. CRD hand book of mariculture 2nd Edition Vol 1 (ed. James. P. Mc. Vey). *Crustacean Aquaculture,* pp. 275-287.

Jayarajan, R., Purushotham, J. S. Subbarao, V. K. Joshua and Remesh Babu, K. R., 1987. An economic analysis of prawn culture in Andhra Pradesh. Some preliminary findings, *In:* Natl. Symp. on Research and Development in Marine Fisheries, Mandapam Camp (India), 16 Sep 1987 CMFRI Bull., 44: 403-406.

Jayaraman, R., Seshappa, G., Mohammed, K. H. and Bapat, S. V., 1959. Observations on the trawl fisheries of the Bombay and Saurashtra waters. 1946-50 to 1954-55. *Indian J. Fish.,* 6(1): 58-144.

Jayaraman, R., 1987. An economic analysis of production and marketing of Indian shrimp for export. M.F.Sc. Thesis. Tamil Nadu Agricultural University, Tuticorin, 119 pp.

Job, T. J. and Pantulu, V. R., 1953. Fish trapping in India *J. Asiatic Soc. Sci.* 19 (2): 175-196.

Johansson, B., 1997. Behavioural response to gradually declining oxygen concentration by Baltic sea macrobenthic crustaceans. *Mar. Biol.* 129(1): 71-78.

Jones, R., 1984. Assessing the effects of changes in exploitation pattern using length composition data, FAO Fish. Tech. Pap. No., 256, 118 pp.

Jose, M. M., Mathew, P. M. and Susheela, J., 1987. Feasibility and economic viability of selective culture of *Penaeus indicus* in Pokkali fields. In: Proc. Nat. Symp. Estuarine Management 4-5 June, 1987, Thiruvananthapuram. (ed. Nair, N.B.), pp. 379-381.

Joseph, K. M. and Sebastain, A. V., 1964. The Effect of Mesh Size on the Fishing Efficiency of Sardine Gill Nets, *Fish. Technol.,* 1(2): 180-82.

Kagwade, P.V., 1972. The fishery of *heptodactylus* cuv. and val. in India. 13(3): 384-401.

Karunasinghe, W. P. N. and Wijeyarantne, M. J. S., 1991. Selectivity Estimates for *Amblygaster sirm* (Clupeidae) in the Small-meshed gill net fishery on the west coast of Sri Lanka, *Fish. Res.*, 10: 199-205.

Kathirvel, M., 1978. Harvesting and marketing of cultured prawns. Special. Bull. Centr. Mar. Fish. Res. Inst. 3: 121-127.

Kawamoto, N. Y., 1955. Experiments with the fish gathering lamp. *In:* Proc. IPFC, 6: 273-280.

Kawamoto, N. Y., 1959. The significance of the quality of light for the attraction of fish. In modern fishing gear of the world, edited by H. Kristjonsson. Fishing News Books Ltd., London.,1: 553-5.

Kennedy, W. A., 1950. The determination of optimum size of mesh for gill nets in lake Manitoba. Trans. Am. Fish. Soc., 79: 167-179.

Khan, A. A., George, N. A. and Pandy, O. P., 1975. On the fishing power of monofilament and multifilament gill nets, *Fish. Technol.,* 12(1): 64-66.

Klust, G., 1959. Relative Efficiency of Synthetic Fibres in fishing especially in Germany, In: Modern Fishing Gear of the World. Vol.1, Kristjonsson, H. (Ed.), Fishing News (Books)Ltd., London, pp.139-146.

Klust, G., 1960., Synthetic net materials for fine gill nets. Fisheries Zietung 68(2): 38-40.

Klust, G., 1982 . Netting Materials for Fishing Gear, FAO Fishing Manual, Fishing News Books (Ltd.), England, 192 p.

Kurien, C. V. and Sebastian, V. D., 1986. Prawn and Prawn Fisheries of India. Hindustan Publishing Corporation printing press, Delhi- 110007, India: 286 p.

Kurien, C. V., Pillai, V. K. and Nair, G. S., 1952. Use of lights of different intensity and colour in luring fish. *Curr. Sci.,* 21: 130-131.

Kurien, C. V and Sebastian, V. D., 1976. Prawns and Prawn Fishing of India. Hindustan Publishing Corporation Printing Press, Delhi, India: 114 p.

Kurup, B. M. and Samuel, C. T., 1983. Systematics and distribution of fishes of the family Leognathidae (pisces) of the Vembanad lake, Kerala (S. India). Rec. Zool. Sur. India, 80: 387-411.

Kurup, B. M. and Samuel, C. T., 1985. Fishing gear and fishing methods in Vembanad Lake. Harvest and Post harvest Technology of Fish. Publ by Society of Fisheries Technologists (India), Cochin, pp. 232-219.

Kurup, B. M., Sebastian, M. J., Sankaran, T. M. and Rabindranath, P., 1992. Exploited fishery resources of the Vembanad Lake: Fishery based on Pokkali fields and polders. *Fish. Technol.*, 29 (1): 21-26.

Kurup, B. M., Sebastian, M. J., Sankaran, T. M. and Ravindranath, P., 1993. An account of inland fishing gear and fishing methods of Kerala. *In:* Low Energy Fishing, Society of Fisheries Technologists (India), Cochin, pp. 145-151.

Kusaka, T., 1965. Fish gathering and submarine illumination of fluorescent discharge lamps. *Bull. Jap. Soc. Sci. Fish.*, 31(3): 187-91.

Lakshmi, G. J., Venkataramiah, A. and Gunter, G., 1976. Effects of salinity and photoperiod on the burying behaviour of brown shrimp *Penaeus aztecus* Ives. *Aquaculture*, 8: 327-336.

Lawler, G. M., 1950. The use of nylon netting in the Lake Erie white fish. Canadien Fish Culturist, 7: 22-25.

LeReste, L., 1971. Rythme saisonnier de la reproduction, migration croissance des post-larvaes vs et des jeunes chezlacrevepte, *P. indicus* H. Milne Edwards de la Baie d'ambaro Cote N.O. de Madagascar. Cah. ORSTOM (Ser. Oceanogr.), 9(3): 279-292.

Liu, F. H., 1957. Rep. Inst. Fish. Biol. Ministry of Economic Affairs and National Taiwan Iniv., 12: 1-3.

Losanes, L. P., Matuda, K., Machii, T. and Koike, A., 1992. Catching efficiency and selectivity of entangling nets. *Fish. Res.*, 13: 9-23.

Losordo, M. T., Wng. J. K., Brooks, M. J. and Lam C. Y., 1986. A mechanized seine harvest system for freshwater prawns. *Aquacultural Engineering,* pp.1-15.

Maeda, H., 1951. Analytical studies on marine lamp-communities. Publ. Seto Mar. Biol.Lab. 1(4): 37-55.

Mammen, T. L., Pannicker, G. N., Shenoy, A. S., George, E. L., Varghese, A. G. and Chandran, K. K., 1979. Shrimp farming demonstration by MPEDA, newsletter, Sept-Oct, CIFE, Versova, Mumbai, pp. 80-91.

Manci, W. E., Malison, J. A., Kayes, T. B. and Kuczynski, T. E., 1983. Harvesting photopositive juvenile fish from a pond using a lift net and light. Aquaculture, 34, (1-2): 157-164.

Masuda, L. and Matuda, K., 1976. Studies on the catching efficiency of gensiki Ami, a bottom drift net 2. On the behaviour of the bag net. *Bull Jap. Soc. Sci. Fish.*, 42 (7): 731-737.

Mathai, T. J., Rajan Abraham. A., Sulochanan, P. and Sadanandan, K. A., 1971. Preliminary observations on the lunar and tidal influences on the catches of seer by gill nets. *Fish. Technol.,* 8(1): 65-68.

Mathai, T. J. and George, N. A., 1972. A Note on the Comparative Catch Efficiency of Nylon over Cotton Gill Nets in Reservoir Fishing, *Fish. Technol.,* 9(1): 81-82.

Mathai, T. J., George, T. P., Sadanandan, K. A., George, N. A. and Nair, A. K. K., 1990. Studies on Prawn fishing by Gill Netting, *Fishing Chimes*, 10(9): 36-38.

Mathai, T. J., Vijayan, V., Abbas, M. S., Doss, R. S. M., and Iyer, H. K., 1993. Mesh selectivity studies on mackerel gill nets, Proc. on the National Workshop on Low Energy Fishing 8-9 August ,1991, Kochi. Society of Fisheries Technologists (India), Kochi, pp. 183-190.

Mathew, P. M. and George, K. M., 1987. Preliminary observations on paddy-cum-fish culture in pokkali fields. *In*: Proc. Nat. Symp. Estuarine Management 4- 5 June, 1987, (ed. Nair, N.B.). Thiruvananthapuram, pp. 382-388.

Mathew, P. M., 1993. Selective culture of prawn in pokkali fields. *In:* Proc. of The National Seminar on Aquaculture Development in India Problems and Prospects, 27-29 November, 1990. (ed. Natarajan, P. Jayaprakash, V.). Kerala Univ., Thiruvananthapuram, India: 59-66.

Mc Combie, A. M. and Fry, F. E. J., 1960. Selectivity of Gill Net for Lake Whitefish, *Coregonus clupeaformis, Trans Am. Fish. Soc.,* 89: 176-184.

Mc Combie, A. M., 1961. Gill net selectivity of lake white fish from Goderich-Bayfield area. Lake Huron. *Trans. Am. Fish. Soc.,* 90: 337-340.

Mc Combie. A. M. and Berst. A. H., 1969. Some effects of shape and structure of fish on selectivity of gill nets. *J. Fish. Res. Board Can.*, 26 (10): 2681-2689.

Menasveta, P. and Higuchi, M., 1983. Operation manual for aquaculture development project in Thailand. Consultancy report to Asian Development Bank, pp. 141.

Menon, M. K., 1954. On the paddy field prawn fishery of Travancore Cochin and an experiment in prawn culture. *In:* Proc. IPFC., 5(2): 131-135.

Menon, M. K. and Raman, K., 1961. Observations on the prawn fishery off Cochin backwaters with special reference to stake net catches. *Indian. J. Fish.,* 8 (10): 1-23.

Miyamoto, H., 1962. A field manual suggested for fishing gear surveys (In Mimeo), Central Institute of Fisheries Technology, 15 p.

Mohammed, K. H. and Rao, P.V., 1971. Estuarine phase in the life history of commercial prawns of the west coast of India. *J. Mar. Boil. Ass. India,* 13(2): 149-161.

Mohan Rajan, K. V., George, M. P., Doss, R. S. M. and Pravin, P., 1991. Studies on polypropylene gill nets, *Fish. Technol.,* 28: 1-4.

Mohanty, S. K., 1988. BFFDA's achievement in prawn farming in Orissa. Seminar on status and prospects of brackishwater aquaculture in Orissa. Part 14 October, 1988. Central Institute of Brackishwater Aquaculture, Special Publication, pp. 68-88.

Mohapatra, C. R., 1988. Present status of brackishwater aquaculture in Orissa. Seminar on status and prospects of brackishwater aquaculture in Orissa. Part 14 October, 1988. Central Institute of Brackishwater Aquaculture, Special Publication, pp. 59-67.

Molin, G., 1950. The applicability of nylon tread for the manufacture of fishing gear. Sevensk Fishcherei Tidstkrift, 59(3): 42-46.

Molin, G., 1956. Results of Nylon fishing tests in Lake Malaren. Sevensk Fishcherei Tidstkrift, 65 (3): 40-46.

Muthu, M. S., 1978a. A general review of penaeid prawn culture. Summer Institute in breeding and rearing of marine prawns. CMFRI Spl. Pbln., 3: 25-33.

Muthu, M. S., 1978b. Site selection and type of farms for coastal aquaculture of prawns. *In:* Proc. First National Symposium on Shrimp Farming. Bombay, 16-18 August 1978, pp. 97-106.

Nagaraj, M. and Neelakantan, B., 1982. Prawn culture in the paddy fields of Uttara Kannada District, Karnataka. Proc. of the symposium on coastal aquaculture, held-at-Cochin from January 12 to 18, 1980. Part-1:-Prawn-culture. Marine Biological Assoc. of India, Cochin, India. No. 6: 392-393.

Naik, D. and Pascoe, S., 1996. Optimal harvesting strategies in sea bream and tiger prawn (*Penaeus monodon*) culture. *CEMARE.*, Res. Pap. No. 104, 14 p.

Nedelec, C., 1975. FAO Catalogue of Small Scale Fishing Gear, Fishing News Books (Ltd)., Farnham, Surrey, England: 191 p.

Njoku, D. C., 1991. Comparative Efficiency and Techno-Economics of Multifilament and Monofilament Gillnets on the Oguta lake, Nigeria, *Fish. Research.*, 12: 23-30.

Nomura, M., 1959. Modern Fishing Gear of the World. Fishing News (Books) Ltd., London, pp. 550-552.

Nomura, M., 1961, Studies on Gill Nets, 1. Performance of gill Nets and Reaction of fish to the Net (in Japanese with English summary), Bull. Tokai. Reg. Fish. Res. Lab., 30: 9-56.

Olsen, S., 1959. Mesh Selection in Herring gill net. *J. Fish. Res. Board. Can.* 16: 339-349.

Otubusin, S.O., 1990. Effects of lunar periods and some other parameters on fish catch in the lake Kainiji, Nigeria. *Fish. Research*, 8: 223-245.

Pai, M.V., Somavanshi, V.S. and Telang, K.Y., 1982. A case study of economics of a traditional prawn culture farm in the North Kanara dist, Karnataka, India *In:* Proc. of the symposium on coastal aquaculture, held at Cochin from January 12 to 18, 1980. part-1: prawn culture. Marine Biological Assoc of India, Cochin, No. 6, pp. 123 -128.

Pajot, G., 1980a. Improvement of large mesh drift nets for small scale fisheries in Sri Lanka, BOBP/WP/3 (GCP/RAS/040/SWE), 18 pp.

Pajot, G., 1980b. Improvement of large mesh drift nets for small scale fisheries in Bangladesh. BOBP/WP/5 (GCP/RAS/040/SWE), 14 pp.

Pajot, G. and Das, T.K., 1981. Trials in Bangladesh of Large Mesh Driftnet of Light Construction, BOBP/WP/12. Madras, India, 15 pp.

Pajot, G. and Das, T.K., 1984. Fishing Trials with Small-Mesh Driftnet in Bangladesh, BOBP/WP/28. Madras, India, 13 pp.

Pajot, G., 1989. Shrimp fisheries in the Bay of Bengal, BOBP/WP/58. Madras, India, 61 pp.

Pani, R., 1995. Management practices for shrimp farming. Fish. World 1995. 2(4-5): 38-40.

Panicker, P. A., Sivan, T. M., Mhalathkar, H. N. and George, P. M., 1978. Selectivity of gillnets for *Hilsa toli* and *Pampus argenteus*. *Fish Technol.,* 15: 16-66.

Panikkar, N, K., 1937. The prawn industry of the Malabar coast. *J. Bombay Nat. Hist. Soc.*, 39 (2): 343-353.

Panikkar. N, K. and Menon, M. K., 1956. Prawn fisheries of India. *In:* Proc. IPFC., 6(3): 328 .

Pati, S., 1981. Observations on the lunar and tidal influence on gill netting in the Bay of Bengal. *Fish. Technol.,* 18: 25-27.

Pauly, D., 1984. Fish population dynamics in tropical water, A manual for use with programmable calculations 9ICLARM studies and reviews) ICLARM, Manila, Philippines, 325 pp.

Pauly, K. V., 1991. Studies on the commercially important fishing gears of Vembanad lake. Ph.D thesis Submitted to Cochin University of Science and Technology, Cochin, pp. 171.

Percier, A., 1959. Specification of fishing gear. Modern Fishing Gear of the World. I. Publ. Fishing News (Books) Ltd., Surrey, England, pp. 262-263.

Peterson, A. E., 1954. The selective action of gill nets on Fraser River. Sockeye. Salmon. *Fish. Commn.* 5: 101 p.

Pillai, N. S., Boopendranath, M. R. and Kunjipalu, K. K., 1989. Studies on the suitability of HDPE material for gill nets, *Fish. Technol.,* 26:1-3

Pillai, S. M. and Krishnan, L., 1998. Biology and fishery of *Penaeus indicus* from traditional fields. *In*: Advances and Priorities in Fisheries Technology (ed. Balachandran, K. K. Iyer, T. S. G. Madhavan, P., Joseph, J. Perigreen, P. A., Raghunath, M. R. and Varghese, M. D.), Society of Fisheries Technologists (India), Cochin, pp. 48-52.

Pillay, T. V. R., 1954. The ecology of a Brackishwater Bheri with special reference to the fish-cultural practices and the biotic interaction. Proc. Nat. Inst. Sci. India 20 (4): 399-427.

Prabhudeva, K. N., Basavakumar, K. V. and Patil, S. J., 1990 . A breakthrough in tiger prawn culture in Karnataka. *Fishing Chimes,* 10(4): 27 & 29-30.

Purushan, K. S. and Rajendran, C. G., 1984. Prawn production in Kerala, budding or withering. *Seafood Export Journal,* 16(2): 27-31.

Purushan, K. S., 1987. Economics of traditional prawn farming in Kerala. *Seafood Export Journal,* 19 (4): 15-19.

Purushan, K. S., 1989. Semi intensive shrimp farming and its relevance in Kerala. *Seafood Export Journal,* 21, (3): 9-15.

Purushan, K. S., 1995. Adaptive farming technology: A boon to sustainable shrimp production from Kerala. *Seafood Export Journal,* 26(12): 5-11.

Purushan, K. S., 1996a. Challenging scenario of scientific shrimp farming in India -An overview. *Seafood Export Journal,* 27(2): 17-23.

Purushan, K. S., 1996b. Sustainable shrimp production from traditional culture systems in Kerala: An improved farming practice. *Fishing Chimes,* (16)7: 33-35.

Purushan, K. S., 1996c. Traditional methods of prawn farming in India -- different farming systems-merits and demerits evaluation of production economics and its scope for avocation and rural development. *Seafood. Export. Journal,* 27(3): 11-15.

Pycha, R. I., 1962. The relative efficiency of nylon and cotton gill nets for taking trout in Lake Superior. *J. Fish. Res. Board Can.,* 19: 1085-1094.

Racek, A. A., 1959. Prawn investigations in eastern Australia, New South Whales, State Fisheries Research Bulletin No.6, 1-57 pp.

Radhalakshmi, K. and Nayar, S. G., 1985. Fishing experiments with newer materials. *In.* Harvest and post-harvest technology of fish (ed. Ravindran, K., Unnikrishnan Nair, N., Perigreen, P. A., Madhavan, P., Gopalakrishana Pillai, A. G., Panicker, P. A. and Mary Thomas) Society of Fisheries Technologists (India), Cochin, pp. 262-263.

Raje, P. G. and Radade, M. A., 1980. Economical implications of shrimp farming, *In:* Proc. First National Symposium on Shrimp Farming. Bombay, 16 – 18 August 1978, pp.123-130.

Rajendran, M., 1980. A study on market. Market structure and marketing of prawns in Mandapam block. Ramachandrapuram district. M.Sc. (Ag.) Thesis. Tamil Nadu Agricultural University Coimbatore, 126 pp.

Rajyalakshmi, T., 1980. Manual of brackishwater aquaculture in India. CIFRI, Barackpore, W. Bengal, 128 pp.

Ramakrishna, K. V., Rao, G. R., Prasadam, R. D., Raman, K., Kadir, P. M. A. Krishnan, S. and Joseph, K. O., 1982. Observations on the mixed culture of brackishwater fishes and prawns in a pond at Adayar, Madras. Proc. of the symposium on coastal aquaculture, held at Cochin from (January 12 to 18, 1980). Part-1 prawn culture. Marine Biological Assoc. of India, Cochin India 1982. No. 6, pp. 244-250.

Ramamurthy, S. and Muthu, M. S., 1969. Prawn fishing methods. *Bull. Centr. Mar. Fish. Res. Inst.* 14, pp. 235-257.

Raman, K. and Menon, M. K., 1963. A preliminary note on an experiment in paddy field prawn fishing. *Indian. J. Fish.*, 10, pp. 33 – 39.

Rani, U. G., Reddy, T. C. and Ravindranath. K., 1993. Economics of brackishwater prawn farming in Nellore district of Andhra Pradesh State, India. *J. Aqua. Trop.*, 8: 221-230.

Rao, J. S., Satyanarayana, A. V. V., Naidu, R. M., Rama Rao, S. V. S. and Naryanappa, G., 1985. Indigenous gear of Andhra coast - A brief account. *In* (ed. Ravindran, K., Unnikrishnan Nair, N., Perigreen, P. A., Madhavan, P., Gopalakrishana Pillai, A. G., Panicker, P. A. and Mary Thomas) Society of Fisheries Technologists (India), Cochin., pp. 292 -295

Rao. P. S., Krishna, K., Lakshmanan, P. T. Agarwal. A. and Chakraborty, R., 1986. Raw material supply to shrimp freezing plants: some significant aspects. *Fish. Technol.*, 23(1) :38-42.

Reddi, D. V., 1980. Economics of shrimp farming in Karnataka area, *In:* First National Symposium on Shrimp Farming. Bombay, 16 – 18 August 1978: 139-141.

Regier, H. A. and Robertson, D. S., 1966. Selectivity of Gill Nets, Especially to Lake White Fish. *Res., Board Can.*, 23: 423-454.

Reis, E. G. and Pawson, M. G., 1992. Determination of Gill Net Selectivity for Bass (*Disentrarchus Labsase* L.) using Commercial Catch Data, *Fish. Res.*, 13: 173-187.

Reisnger, E. A., Jr., 1985. Harvesting cultured shrimp . *In* Chamberlain , G.W., M.G. Haby and R.J. Miget (eds). *Texas Shrimp Farming Manual. Texas Agricult, Ext. Service,* Texas A&M Univ., College Station, TX, pp. 49 -56.

Rounsefell, G. A. and Everhart, W. H., 1953. Fishery Science, its methods and applications. New York, John Wiley and Sons, 444 p.

Ruello, N. V., 1975. Geographical distribution, growth and breeding migration of eastern Australian king prawn *Penaeus plebejus* (Hess). *Aust. J. Mar. Freshwater Res.*, 26: 343-354.

Saha, G. N., Thakurta, S. C., Laha, G. C., Naskar, K. R., Das, P. B. and Chatterjee, S. K., 1986. Ecology and Fishery Management of Brackishwater Bheries in West Bengal. Central Inland Fisheries Research Institute, Barrackpore. Bulletin No. 46: 23.

Sakthivel, M., 1998. Shrimp culture in India. Where is it now? Where is it going? BOBP, 2(11): 4-6.

Salvanes, A. G. V., 1991. The selectivity of cod (Gadus Morhua L) in two experimental Trammel-nets and one gill net. *Fish. Res.,* 10: 265-285.

Sathiadhas, R., Panikkar, K. K. P., Satyavan, U. K. and Jacob. T., 1989. Economic evaluation of paddy prawn integrated farming in Kerala. *Seafood Export Journal,* 21(11): 9-21.

Schallck, W., 1943. The reaction of certain crustacea to direct and diffuse light. *Biol. Bull.*, 84, pp. 98-105.

SEAFDEC, 1984. Prawn industry development in Philippines. *In.* Proc. National Prawn Industry Development Workshop. Aquaculture Dept., Southeast Asian Fisheries Devel. Centre, Iloilo, Philippines, pp. 69-70.

SEAFDEC, 1986. Fishing gear and methods in South East Asia: Thailand. TD/RES/9, pp.

Selvakumar, R. A., George, M. J., Achuthankutty, C. T., 1977. Penaeid prawn larval abundance in the Mandovi Estuary, Goa. *Indian. J. Mar. Sci,*. 6(2): 160-162.

Shabtay, A.,1956. Experiments with Perlon gill nets at the Fisheries School. Fishermen's Bulletin, 7:1.

Shigueno, K., 1969. Problems in prawn cultures. Amerind Publishing Co., New Delhi, India, 103 pp.

Shigueno, K., 1978. Shrimp culture in Japan. Asso. Intl. Technical, Promotion, Tokyo, Japan, 153 pp.

Shimozaki, Y., 1964. Production and characteristics of synthetic nets and ropes in Japan, *In:* Modern Fishing Gear of the World Vol 2. (ed. Kristjonsson, H.), Fishing News Books (Ltd.), London, pp. 66-70.

Shon, T. J., 1978. On the catch of gill nets in the Jeju island, Comparison of mackerel catch in monofilament and multifilament gill nets. Bull. Korean. Fish. Soc., 8(1): 7-10.

Shon, T. J., 1985. Mesh Selectivity of gill net for anchovy. *Engraulis japonica. Bull. Korean. Fish. Soc.,* 18(6): 506-510.

Siddiqui, Q. A. Alhinty, H.M. Amjed Ali, S., 1995. Effects of harvesting methods on population structure, growth and yield of freshwater prawn, *Macrobrachium rosenbergii*, cultured at two densities. *J. Appl. Aquacult.*, 5, (3): 9-20.

Silas, E. G., 1980. Status of prawn culture in India and strategy for its future development. Proc. First National Symposium on Shrimp Farming. Bombay, 16 – 18 August, 1978, pp. 209-218.

Singh, I. J., and Pandey, V, K., 1968. Fish production functions for West Godavari district (A.P). *Indian J. Agric. Econ.*, 23(4): 255-258.

Sivadas, T. K., 1978. In-situ temperature and salinity meter. *Fish. Technol.*, 15(1): 77-80.

Sivadas, T. K., 1980. Marine electronic instruments developed by CIFT, *In:* Institute of electrical and electronic engineers, 2-5 November, Thiruvananthapuram.

Sivadas, T. K., 1987. Instrumentation technology developed by CIFT for environment borne programme, CIFT, Cochin.

Sparre, P., Ursin, E. and Venema, S.C., 1989. Introduction to tropical fish stock assessment Part – I. Manual, FAO Fish. Tech.Paper. No. 306. 1 Rome, FAO, 337 pp.

Sreekrishna, Y., Rao, S. J., Dawson, P., Mathai, T. J. and Sulochanan, P., 1972. Mesh selectivity for spotted seer *Scomberomorus guttatus* (Bloch and Schaneeder), *Fish. Technol.,* 9(2): 133-138.

Srinath, K., Sridhar M., Kartha, P. N. R. and Mohanan, A. N., 2000. Group farming for sustainable aquaculture. *Ocean and Coastal Management* 43 (7): 557-571.

Srivastava, U. K., Singh, A. and Santhakumar, M. J., 1983. Economics of brackishwater culture in India: Some preliminary evidences. *In* : (ed. Srivastava, U. K. and Reddy, M. D.). Fisheries development in India. Concept Publ. Co., New Delhi, pp. 397- 409.

Steinberg, R., 1964. Monofilament gillnets in fresh water experiment and practice. Modern Fishing Gear of the World 2. Publ. Fishing News (Books) Ltd., Surrey, England, pp. 111-115.

Stickney, R. R., 1994. Principles of Aquaculture, John Wiley & Sons inc , New York, 502 pp.

Subramanyam, M., 1965. Lunar, diurnal and tidal periodicity in relation to the prawn abundance and migration in the Godavari estuarine systems. *Fish. Technol.* 2(1): 26-33.

Sulochanan, P., George, V. C. and Naidu, R. M., 1968. Experimental fishing in Hirakud reservoir, Orissa, *Fish. Technol.,* 5(2):18.

Sulochanan, P., Sadanandan, K. A., Mathai, J. P. and Abbas, S. M., 1975. Selectivity of Gill Nets for *Scomberomorous commersoni, Fish. Technol.,* 12(1): 52-59.

Suseelan, C., 1975. Resources and exploitation of juvenile penaeid prawns from Manakkudy estuary. *Indian. J. Fish.*, 22(1):96-106.

Suseelan, C. and Kathirvel, M., 1982. A study on the prawns of Ashtamudi backwaters in Kerala with special reference to penaeids. *Indian. J. Fish.*, 29(1-2): 71-78.

Tamura, T., 1959. Fundamental studies on the visual sense in fish, *In*: H. Kristjonsson (Ed.), Modern fishing gear of the world., Vol. 1 Fishing News Books Ltd., London, pp. 543-547.

Tharakan, A., 1991. Shrimp production in India - A review. *Seafood. Export. Journal*, 23(4) : 5-14.

Thomas, S. N., Kuttappan, A. C., Varghese. P., George V.C. and Iyer, H.K. 1993. Relative Efficiency of gill nets and Trammel Nets : A Preliminary Study, *In* : Low Energy Fishing, (Special Issue on Low Energy Fishing) Society of Fisheries Technologists (India), Cochin, pp. 191- 194.

Thomas, S. N., Edwin, L., George, V. C. and Iyer, H. K. 1999. Size composition and abundance of penaeid prawns in stake nets with reference to lunar phase. Proc. Fourth Indian Fisheries Forum, 24-28 November, 1996, Kochi, pp. 463-466.

Thomas, S. N., 2001. Gill nets of Kerala: A study on technological and operational aspects. Ph.D. Thesis, Cochin University of Science and Technology, Cochin, 217 pp.

Thomas, S. N., Edwin, L. and George, V.C., 2003. Catching Efficiency of gill nets and Trammel Nets for penaeid prawns. *Fish. Res.*, 60:141-150.

Tseng, W. Y., 1988. Shrimp mariculture – A practical manual, W.S. Aquaculture, Canann International Ptv. Ltd. Brisbane, Australia 2nd Edition, October, 1988.

Unnithan, K. A., 1985. A guide to prawn farming in Kerala. CMFRI Spec. Publ. Cochin, India No. 21, 92 pp.

Unnithan, K. A., 1996. Sustainable shrimp farming (Malayalam) Extension series 10-A CMFRI. Cochin.

Unnithan, K. A., 2000. Shrimp farming – a status review. *In*: Marine Fisheries Research and Management. (ed. Pillai, V. N. and Menon, N. G.). Central Marine Fisheries Research Institute, Cochin, pp. 724-746.

Vance, D. J., Heales, D. S. and Loneragan, N. R., 1994. Seasonal, diet and tidal variation in beam trawl catches in juvenile grooved tiger prawns, *Penaeus semisulcatus* (Decapoda: Penaeidae), in the Embley River, north-eastern Gulf of Carpenteria, Australia. *Aust. J. Mar. Freshwater Res.*, 45, pp. 35-42.

Vasudevan, S. and Subramoniam, T., 1985. Seasonal abundance of penaeid prawn seed in the Ennore Estuary, Madras in relation to hydrography and lunar phase. *In:* Proc. First International Conference on the culture of penaeid prawns shrimps, iloilo city, Philippines, (ed. Taki, Y., Primavera, J. H. and Llobrera, J. A.). 4-7 December 1984. Southeast Asian Fisheries Development Cent., Iloilo City Philippines, 175 pp.

Verghese, A. G., 2001. Status of Export-oriented shrimp/prawn farming in Kerala. *Fishing Chimes,* 20(10&11): 65-67.

Verghese, P. U., Ravichandran, P., Pillai, S. M., 1982. Growth and production of *Penaeus monodon* Fabricius in short-term field rearing experiments. Cochin (India). Proc. of the symposium on coastal aquaculture, Symp. on Coastal Aquaculture, Cochin, (January 12 to 18, 1980). Part-1 prawn culture. Marine Biological Assoc. of India, Cochin, India, pp. 419.

Verheyen, F. J., 1959, Attraction of fish by the use of light. (ed. Kristjonsson, H.)., Modern fishing gear of the world., Vol. 1 Fishing News Books (Ltd.), London, pp. 548-549.

Villalon, J. R., 1991. Practical manual for semi-intensive commercial production of marine shrimp. TAMU-SG. Texas, A&M University Sea Grant College Program by the National Sea Grant Office, national Oceanic and Atmospheric Administration, U.S. Department of Commerce, pp. 99-501

Wassenberg, T. J. and Hill, B. J., 1994. Laboratory study of the effect of light on the emergence behaviour of eight species of commercially important adult penaeid prawns. *Aust. J. Mar. Freshwater Res.,* 45(1): 43-50.

Wickham, D. A., 1970. Collecting coastal pelagic fishes with artificial light and a 5-m lift net. *Commer. Fish. Rev.,* 32 (12): 52-57.

Wickham, D. A., 1973. Attracting and controlling coastal pelagic fish with nightlights. *Trans. Am. Fish. Soc.,* 102(4): 816-25.

Williamson, M. R. and Wong, J. K., 1982. An improved harvesting net for fresh water prawns. *Aquacultural Engineering* : 81-91.

Yap, W. G., 2001. The low down on world shrimp culture –1. Infofish International, 2: 32-36.

Yatsu, A. and Watanabe, Y., 1987. Mesh Selectivity of Gill Nets for Slendr Tuna (*Allothunnes fallai* serventy (Scombridae), *Bull. Jap. Soc. Sci. Fish.,* 53(6): 947.

Yoshimuta, C. and Mitsugi, S., 1963. A direct current mercury vapour lamp for attracting fish. Bull Tokai Reg. *Fish. Res. Lab.*, (37): 51-61.

Zaucha, J., 1964. New Synthetic Herring Driftnets Used in the North Sea, Modern Fishing Gear of the World Vol. 2. Kristjonsson, H.(Ed.) Fishing News (Books) Ltd., London, pp. 73-87.

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